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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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NOTICES

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SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Plastics in Building

WE have received from the Director of the Building Research Station a copy of the paper read by Mr. R. J. Schaffer earlier this year on "The Use of Plastics in Building" before the Society of Chemical Industry. This paper is an extremely valuable and critical presentation of the plastic-building situation as it exists at present and as such will be welcomed.

The author described the complete structures that have been erected more or less entirely of plastics, including an American example where walls, doors, floor tiles and extruded skirtings and ceiling mouldings were made from synthetic resins, and the "synthetic house" at the 1938 Frankfurt Exhibition, where walls, plumbing, tiles and "timber" were also so constructed. These were exhibition models and obviously bore little relation to economically built houses. Many separate features, however, were of practical interest.

Accepted Building Plastics

Mr. Schaffer described much that had already been adopted in the building industry. Among the numerous moulded fittings already well known he included ball floats, cisterns, draining-boards, window furniture, curtain rails, etc. The laminated series was also already widely used, and he instanced the fitting of wall-coverings in the Coronation Scot, and on liners such as the "Queen Mary" and "Queen Elizabeth." He said that while laminated plastics are much costlier than other wall-facing materials, they are self-coloured and easy to maintain, thus offsetting this disadvantage. On the other hand, the idea of a permanent colour scheme may not appeal to some domestic users.

Resin-moulded plywood, he agreed, is one of the most promising lines of development, especially in the field of prefabrication, since it is so highly resistant to moisture and therefore can be used out of doors. Favourable reports have been received on such house construction from America. Resin impregnated wood finds useful application also, but its cost is at present prohibitive except for heavy-duty floors or for special constructions such as those for withstanding the attacks of "white ants."

Windows and Doors as Possibles

Of special interest was his estimate of the progress made in fabricating plastic window frames and doors. While window frames moulded in one piece have been made for refrigerator display cabinets, the manufacture of plastic window frames for buildings is more difficult, and although there have been several patents there has, as yet, been no production. Plastics will have to compete with the much lower prices of steel and wood, and there is also the necessity of increasing the dimensions to compensate for lower strength and toughness.

Rain-exclusion is a particularly important consideration. The wood or steel frame is designed with weather-checks. To make these in a moulded frame means under-cutting the mould and complicating the moulding operation. This difficulty does not arise if the bars are moulded separately or if they are made by extrusion, but there is then a difficulty in fabrication. It is often remarked that plastics design should not attempt to imitate design in other materials but should follow an independent line and evolve designs suited to the medium and to the manufacturing operations involved. But in seeking to avoid imitation it is also important to recognize and take account of features that are incorporated in existing designs with a specific object in view. The weather-check of a window frame is a case in point. The making of window frames in plastics has been ten-

tatively discussed with several firms in the industry. Their suggestions include conventional and unconventional designs, either moulded as complete units or fabricated from moulded or extruded sections. The moulding of whole frames would require the use of a large press and involve the rather speculative expenditure of £1,000 or more on the mould. Estimates submitted suggest that window frames in plastics would cost from 4s. to 7s. per sq. ft., plus the cost of fittings, whereas steel frames, complete with fittings, painted one coat, and delivered, cost only 1s. 4d. to 1s. 9d. per sq. ft.

Doors are made with plastics sheets fixed to a wooden framework, and there are proposals for making the framework from moulded units. Whether such a framework can be produced at an economic price and can withstand the hard usage to which doors are subjected remains to be seen.

Load-bearing Materials Under Criticism

The author has carefully studied plastics as load-bearing materials, although he admits that the plastics industry itself has not advocated such uses. While they can be made with a reasonably high tensile strength and while the specific gravity is low compared with steel, yet plastics so far available are not especially suitable because of the low modulus of elasticity when compared with tensile strength, and are lacking in ductility. He concludes that the mechanical properties will need to be improved if plastics are to be used as load-bearing materials and compete with steel and wood.

High-frequency Heating

A SHORT time ago, in an editorial in these pages, we described in general terms the rather obvious high lights in the life of the plastics industry, purely from the economic angle. To do the same for the scientific, that is chemical, physical or engineering point of view would need much more space and would be more complicated and difficult, although, to some, even more interesting. Rather it is our desire now to draw our readers' attention to one special process or scientific development which, if it has not yet reached the status of high-light in a practical form, does seem to bear the seed of very sound fruit for the plastics industry. We refer to the process of using high-frequency currents for the treatment of synthetic resins and plastics in general as described by Mr. B. J. Branjnikoff on page 362 of this issue.

It has been said, in a moment of enthusiasm, that against the glittering promise of this new method the normally heated press appears but a worn-out, prehistoric instrument. What was meant by this castigation of the hydraulic or mechanical heart of our industry was not that the press itself is at fault, but the method of heating leaves much to be desired. This has been known to all and no doubt it is the height of unscientific method to heat solids by radiation or conduction, especially when the solids happen to be, as plastics all are, non-conductors of heat. Such methods must be wasteful; indeed, although we doubt whether a heat balance of a heated press has or can be struck, it is obvious that the amount of energy at present required to raise an ounce or two of synthetic resin held between the upper and lower portions of a thick steel mould is fantastically high. When coupled with the time factor and the production of thick mouldings, this method of heating can introduce other disadvantages.

The use of high-frequency current, so much fostered and advanced by modern radio technique, is by no means new to the world: It has for a number of years been successfully employed in metallurgy and by the medical profession in "diathermy." The ability to prevent heat wastage or to produce heat exactly where it is wanted within a body has been sought by many.

In the realm of plastics very little useful information has been divulged in the literature, although it is the plastics industry which may receive the greatest

benefit. Applied first, most probably, to the treatment of rubber, the process is in its infancy and, indeed, may be considered to be still in the experimental stage, although some few concerns claim to have passed this and to have entered on a production scale. For example, induction heating has been introduced in the Reed Prentice injection moulding machine.

High-frequency treatment of plastics is equally important to processing other than by pressure and it is perhaps here that we shall see the greater use of the new method, and it is fascinating to consider Mr. Brajnikoff's picture of the production of plastic footwear in a conveyor system.

There is, no doubt, a long and hard road to travel before we shall see "radio" equipment in the average moulding factory. There is as much to simplify in the electrical equipment, especially with regard to secondary coils, as there is in the plastic processing, but we shall eventually, no doubt, reap the benefit.

DR. GORDON KLINE

Last month we had the pleasure of meeting Dr. Gordon Kline, Technical Editor of "Modern Plastics," who came over from the United States of America to collaborate with the plastics industry and Government officials here.

He expressed his keen appreciation of all he had seen and his gratitude for the ready help he had received from plastics concerns and technologists.

U.S. SYNTHETIC RUBBER

In America, "Transport Topics" of July 27 tells us, figures showing that contracts have been placed for the manufacture of 745,000 long tons were submitted to a Senate sub-committee investigating the manufacture of substitutes from farm products by Stanley Crossland, vice-president of the Rubber Reserve Co. The accompanying table shows the capacity of each plant. The scheduled dates of completion all lie between September, 1942, and October, 1943.

PLANTS TO MANUFACTURE SYNTHETIC RUBBER INGREDIENTS

Name	Production Capacity in Short Tons Per Year
Butadiene Plants	
Shell Chemical Co.	30,000
Southern California Gas Co.	25,000
Humble Oil & Refining Co.	30,000
Standard Oil Co. of La	6,200
Standard Oil Co. of La	15,000
Carbide & Carbon Chemical Co.	5,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Carbide & Carbon Chemical Co.	20,000
Atlas Oil & Refining Corp.	12,000
Neches Butane Products Co.	50,000
Neches Butane Products Co.	50,000
Rubber Synthetics Inc.	50,000
Rubber Synthetics Inc.	50,000
Koppers United Co.	20,000
Sinclair Rubber, Inc.	50,000
Cities Service Refining Co.	55,000
Total Butadiene	648,200
Styrene Plants	
Dow Chemical Co.	25,000
Monsanto Chemical Co.	10,000
Monsanto Chemical Co.	10,000
Monsanto Chemical Co.	5,000
Monsanto Chemical Co.	5,000
Carbide & Carbon Chemical Co	12,500
Carbide & Carbon Chemical Co	12,500
Dow Chemical Co.	4,200
Dow Chemical Co.	25,000
Dow Chemical Co.	25,000
Dow Chemical Co.	12,500
Koppers United Co.	35,000
Total Styrene	181,700
Total ingredients	829,900

PLANTS TO MANUFACTURE FINISHED SYNTHETIC RUBBER

	Long Tons Per Year
Copolymer Synthetic Rubber Plants	
Firestone Tire & Rubber Co.	30,000
Firestone Tire & Rubber Co.	15,000
Firestone Tire & Rubber Co.	15,000
Firestone Tire & Rubber Co.	15,000
Firestone Tire & Rubber Co.	15,000
Firestone Tire & Rubber Co.	15,000
Firestone Tire & Rubber Co.	15,000
Goodyear Tire & Rubber Co.	15,000
Goodyear Tire & Rubber Co.	15,000
Goodyear Tire & Rubber Co.	30,000
Goodyear Tire & Rubber Co.	30,000
Goodyear Tire & Rubber Co.	15,000
Goodyear Tire & Rubber Co.	10,000
Goodyear Tire & Rubber Co.	55,000
The B. F. Goodrich Co. (5 plants)	115,000
U.S. Rubber Co.	30,000
U.S. Rubber Co.	30,000
U.S. Rubber Co.	30,000
U.S. Rubber Co.	15,000
U.S. Rubber Co.	15,000
U.S. Rubber Co.	15,000
U.S. Rubber Co.	15,000
U.S. Rubber Co.	15,000
To be determined	30,000
To be determined	30,000
To be determined	15,000
Total Copolymer rubber	645,000
Butyl Synthetic Rubber Plants	
Standard Oil Co. of La	7,000
Standard Oil Co. of La	33,000
Humble Oil & Refining Co.	20,000
Total Butyl rubber	60,000
Neoprene Synthetic Rubber Plants	
E. I. duPont de Nemours & Co.	10,000
E. I. duPont de Nemours & Co.	10,000
E. I. duPont de Nemours & Co.	20,000
Total Neoprene rubber	40,000
Total synthetic rubber	745,000

Plastic Bearings

By D. WARBURTON BROWN, A.M.I.A.E., M.I.P.I.

Bearings machined and moulded of plastics have proved outstandingly successful in special branches of engineering. These notes include practical data regarding their design and maintenance

THE use of plastic materials of the laminated phenolic type for bearings is now well known, although it is some 15 years ago since such potentialities were first realized.

The rapid improvement in the physical properties of the phenolic materials has made it possible for this type of plastic to replace the more usual bearing materials, such as lignum vitæ, bronze and white metal in a number of cases. Not only has the introduction of plastics resulted in equal performance, but in a vast number of cases the life and power consumption of the bearings has been much improved.

Several grades of phenolic materials can be used for bearings, each type having its own sphere of usefulness. Generally speaking, the laminates, both of the coarse and fine fabric base variety, are used, but in some cases moulded materials of the scrap fabric type can be used with success. In addition to variations in material there are a number of different methods of producing plastic bearings, depending upon the duties which the installation will be called upon to perform.

If the maximum benefit is to be obtained from the use of plastic materials for bearings, it is essential to completely dismiss the usual ideas concerning the design of metal bearings, since the peculiarities of the structure of the synthetic resins make it necessary to work to a new and different set of rules, not only from the point of view of design and construction but also from that of cooling and lubrication.

As has been pointed out, there are various methods of producing plastic bearings, depending upon the nature of the duties which have to be fulfilled. In some cases scraps of resin-impregnated fabric are pressed to form in suitable moulds; in others the bearings are machined from fabric base laminated tubes. It is also sometimes possible to combine the advantages of different types of construction, as, for example, when strips of impregnated fabric material are incorporated in a moulded bearing. In this manner the strength and the good running qualities of the fabric material are combined with the ease of manufacture of the moulded type of bearing.

Tube Material

Bearings machined from tube materials, as shown in Fig. 1, have very good

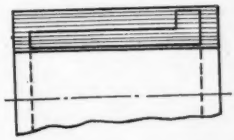


Fig. 1.—Bearing machined from tube.

strength characteristics and running qualities, and are well suited for applications where the bearing will be subjected to impact stresses.

The material used for this type of bearing is made by winding resin-impregnated fabric on to suitable mandrels and pressing in split moulds. In this connection it is worth while to mention that during the moulding of laminated tubes by the method just described a seam of pure resin is formed along the length of the tubes at points corresponding to the mould splits. This seam of resin represents the weakest point in the tube, and if very thin-walled bushes are produced from this type of material, trouble may be encountered due to splitting along the resin seam. The formation of the seam is shown in Fig. 2.

Laminated tubes can be supplied from stock in a wide range of diameters and

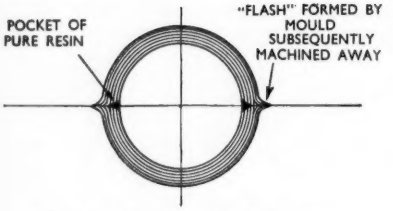


Fig. 2.—Formation of resin pockets.

wall thicknesses. The tube can be readily machined, and bearings or bushes can be turned or milled to the desired form.

Moulded Material

When it is desired to produce bearings by moulding the material used usually consists of irregular scraps of coarse texture fabric which has been impregnated with phenolic resin. This scrap fabric material is pressed together with a percentage of powder material, in moulds of suitable form. In many cases graphite is introduced into the material to ensure good running qualities.

Bearings produced by moulding scrap fabric material have good running properties and satisfactory strength figures. Moulded bearings can be produced in complicated shapes and the finished product requires the minimum of subsequent machining.

The limiting factor in this method of construction is the initial capital outlay for the mould, and in many cases this makes it more economical to use bearings produced by an alternative method even although a considerable amount of machining may be involved. Where the quantities involved, and the shape of the bearing block warrant the outlay on tools, this type will give excellent service.

Stratified and Built-up Construction

This is essentially a variation of the moulded scrap fabric method of construction, and consists of placing layers of impregnated fabric in the mould so that after moulding the running surface of the bearing is, in effect, laminated material. The rest of the block is built up from moulded scrap fabric material (Fig. 3).

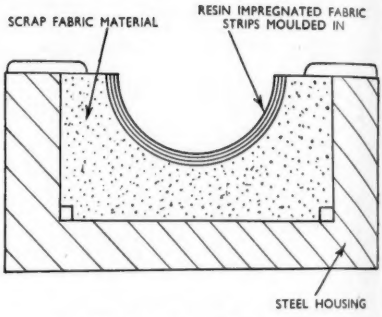


Fig. 3.—Principle of stratified construction.

Bearings produced by this method are very suitable for applications which demand a complicated shape of bearing with a high load-carrying capacity, as bearings of this type combine the ease of production of the moulded bearing with the strength characteristics of the tube-type bearing. It will be realized that the loads are always perpendicular to the direction of the layers of reinforcing fabric so that the danger of splitting is very small.

A type of bearing construction which is widely used for roll mill and marine applications is the built-up strip method. In this type of construction strips or pads of laminated plastic material are let into grooves machined co-axially around the periphery of a steel shell (see Fig. 4). After the strips have been secured in position, laminated thrust faces are fastened to each end of the bearing, and the running surfaces are machined to size. The grooves between the strips of

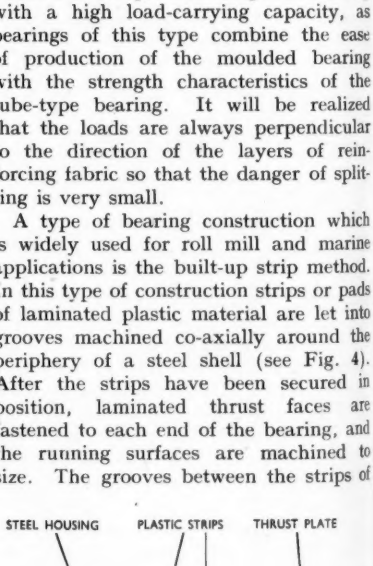


Fig. 4.—Principle of built-up construction.

plastic material are often used as pockets for the lubricant or coolant.

Design of Plastic Bearings

There are three basic rules for the design of plastic bearings, and these are outlined below:—

(1) Owing to the highly elastic and resilient nature of the plastic materials it is essential that the bearing surfaces shall be fully supported by the surrounding metal support. No undercutting of either the bearing or shell is permissible. The correct method of mounting is illustrated in Fig. 5.

(2) The wall thickness of plastic bearings should be made equal to 0.1

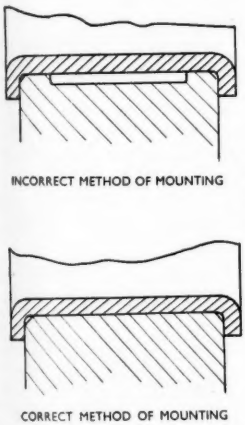


Fig. 5.—Sketch showing correct and incorrect method of mounting plastic bearings.

to 0.15 of the shaft diameter. No useful purpose is served by reducing the wall thickness, since all plastics are poor heat conductors. The only effect of cutting down on the thickness of the wall is a reduction in mechanical strength.

(3) The length of the bearing surface should be made equal to 0.60 to 1.00 of the shaft diameter, the lower of these values being preferable in the interests of adequate cooling of the bearing during operation. If it is necessary to provide greater support the bearing surface should be divided by annular grooves round which the coolant can be circulated. This arrangement is shown in Fig. 6.

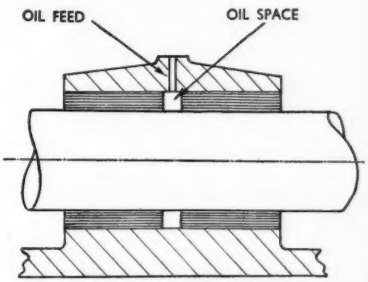


Fig. 6.—Sketch of split plastic bearing.

A few general notes concerning the design of plastic bearings will now be given:—

Materials and Running Qualities

The physical properties of the various types of materials which are used in the construction of plastic bearings are given in Table 1. It must be appreciated that the figures shown are average values only, and although these can be used for preliminary designs, specific information concerning the material which it is proposed to specify should be obtained before final designs are prepared.

Another point which it is necessary to remember is that no indication of the running qualities of the bearing can be obtained from the figures given in Table 1. Thus, for example, in some applications the running qualities of a bearing moulded from scrap fabric material are superior to those of a bush machined from tube stock, although the mechanical properties of the former are lower.

The wearing qualities of a properly designed and lubricated plastic bearing are excellent, and many examples exist which show that the life of plastic bearings operating under arduous conditions may be as much as 10 times as great as metal bearings working under similar conditions.

A further advantage which is possessed by plastic materials which makes them suitable for bearings is that owing to their elastic nature any foreign matter, such,

Table 1.—Physical Properties of Bearing Materials.

Material	Sp. gr.	Tensile strength (lb./sq. in.)	Youngs modulus ($\times 10^6$) (lb./sq. in.)	Compressive strength (lb./sq. in.)	Impact strength (ft. lb.)
Scrap fabric mouldings	1.37 1.40	7,000	0.90	26,000	0.50 3.50
Coarse fabric laminated phenolics ..	1.36 1.38	8,500 10,500	1.00	35,000	20.0
Fine fabric laminated phenolics	1.36 1.38	11,500 16,000	1.00 1.50	35,000	22.0

for example, as grit, becomes embedded in the bearing material, thus minimizing the danger of damage to the shaft.

Friction

The coefficient of friction of plastic bearing materials varies considerably with differing conditions of lubrication and shaft speed, as will be seen from Table 2.

Table 2

	Coefficient of Friction.
(1) Steel on dry laminated material	0.140
(2) Steel on laminated material (normal lubrication, low speed) ...	0.010-0.050
(3) Steel on laminated material (pressure lubrication, high speed) ...	0.003-0.006

The rapid falling off of the coefficient of friction with the introduction of pressure lubrication may be explained by the fact that the oil is taken up by the multitude of fibres which are exposed when the running surface of the bearing is machined. These fibres act as a series of oil-carrying wicks, which form the main structure for retaining the oil film.

The low friction of plastic bearings which have been properly designed results in a very considerable reduction in the power absorption of the installation. Statistics have shown that it is not uncommon when plastic bearings have replaced metal for power savings of as much as 30 per cent. to be obtained.

Pre-treatment, Clearances and Shafts

In order to avoid any movement of the bearing material after final machining has been completed it is desirable to adhere to the following procedure:—The bearing is machined with a finishing allowance on all dimensions; it is then left to soak for about 50 hours in an oil bath maintained at a temperaure of 80 to 90 degrees C. After removal from the bath the outside diameter is machined to finished size, including an " oversize " for pressing into the housing. The oversize varies from about .005 in. for bearings up to 0.75 in. diameter to 0.03 for bearings whose bore is 6 ins. The bearing is then pressed into its housing, and the bore is finished by diamond turning.

The effect of oil and water on the plastic bearing materials makes it necessary to use running clearances which appear large when compared with those used for metal bearings. If the clearances are too small there is a danger of overheating and seizure, although the danger of damaging the shaft is small. For general purposes the clearances should not be less than 0.005 in. to 0.008 in., the larger figure being used for bearings which will be called upon to operate for long periods without a break. Under the influence of oil, water and heat this clearance is considerably reduced, so that more normal conditions prevail in operation.

The shafts used in conjunction with synthetic resin bearings should be hardened and ground and should be perfectly free from surface scratches as these can cause considerable damage to the bearing material.

Shouldered Bearings

When it is desired to incorporate shoulders on bearings to accommodate

thrust forces there are various methods of producing these. If the bearing is moulded the shoulder must be made of equal thickness to the wall of the bearing otherwise unequal cooling of the material will cause internal stresses, resulting in distortion. The correct design for a moulded bearing incorporating a shoulder is shown in Fig. 7.

If only a small shoulder is necessary the most satisfactory and economical method is to produce the bearing from tube material (refer to Fig. 1). When large diameter shoulders are necessary, however, it is best to machine the thrust faces separately from sheet material. The method of doing this is illustrated in Fig. 8.

Lubrication and Cooling

Because of the very poor heat conductivity of plastic materials it is necessary to pay particular attention to the questions of lubrication and cooling, since the performance of plastic bearings is more closely linked with these factors than is the case with metal bearings.

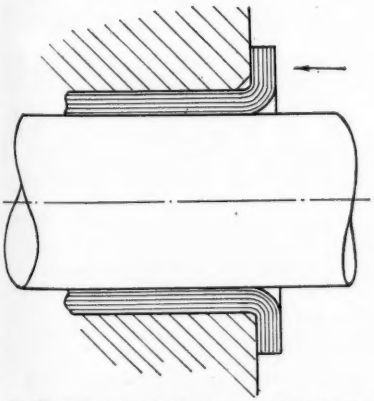


Fig. 7.—Shouldered bearing—moulded type.

If the bearing has been carefully designed with a view to restricting the heat generated by friction to a minimum, and if the operating temperature of the bearing is not allowed to exceed 85 degrees C. there is little danger of seizure

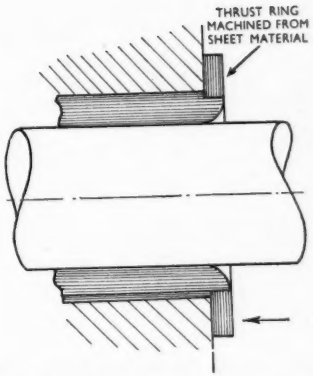


Fig. 8.—Shouldered bearing—composite type.

of the bearing occurring. In certain installations, however, the conditions are so arduous that it becomes necessary to provide additional water cooling in order that the running temperature can be kept down to the required figure.

When this is necessary, additional cooling can sometimes be provided by circulating water through the shafts, but this introduces mechanical difficulties owing to the fact that the water has to be transferred from an outside source to the rotating shaft. In cases where pressure lubrication is used, the oil may be used as a coolant as well as a lubricant, and in these cases the oil should be chosen for its heat-resisting characteristics as well as for its lubrication qualities.

In bearings which are lubricated by grease additional cooling is often obtained by spraying water direct on to the shaft between the bearing blocks as shown in Fig. 9. In certain cases it is possible to use water alone for the lubrication of synthetic resin bearings, but it has been found that in practice the successful operation of plastic bearings is largely dependent upon the careful balancing of lubricant and coolant.

The choice of lubricant is just as important in the case of plastic bearings as when metals are being used. Broadly speaking, lubricants suitable for use with

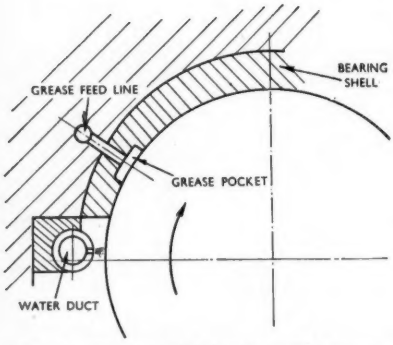


Fig. 9.—Water-cooled bearing with grease lubrication.

plastic bearings should fulfil the conditions which follow.

(1) Greases

(a) Grease having a high resistance to loading should be used so that there is no likelihood of the lubricating film breaking down even under conditions of overload.

(b) The grease should be chosen so that its melting point is well above the maximum operating temperature of the bearing.

(c) When used in conjunction with water cooling it is advisable to use a water-rejecting grease.

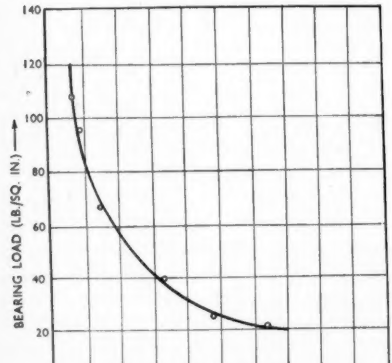


Fig. 10.—Relationship between shaft speed and bearing load.

(2) Oils

(a) Mineral oils only should be used, as vegetable and animal oils are not suitable.

(b) When pressure lubrication is used, high-duty mineral oils having good lubricating qualities should be used.

(c) Generally speaking, the higher the operating temperature of the bearing, the higher should be the viscosity of the oil.

The life of plastic bearings can be prolonged by keeping the friction moment and also the operating temperature down to the lowest possible values. In this connection it should be noted that the peripheral speed of the shaft has a considerable influence on the load capacity of the bearing as well as on the temperatures. Reference to Fig. 10 and Fig. 11 will illustrate this point.

Running-in of Plastic Bearings

In order that the maximum life shall be obtained from plastic bearings care should be taken to run-in the bearings gradually. By so doing any roughness of the machined surfaces is smoothed away by the action of the rotating shaft. This roughness during the early stages increases the friction of the bearing, and it is necessary to increase the load gradually during the running-in period, and to remove it entirely immediately the temperature of the bearing reaches 85 degrees C. The heat should then be

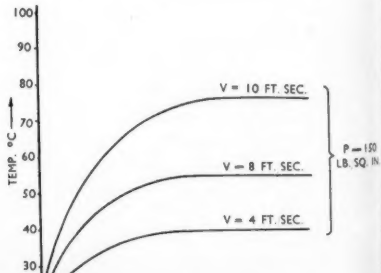


Fig. 11.—Temperature rise as function of shaft speed.

allowed to dissipate before load is again applied.

The running-in should then proceed gradually until maximum load conditions are reached, and under no circumstances should the load be increased at any stage of the running-in period until the temperature remains within the allowed range —that is, from 80 to 85 degrees C. In effect the running-in of plastic bearings is nothing more than a method of improving the running surfaces.

Applications

Up to the present time plastic bearings have been most widely used for heavy rolling mills. Their success in this field is largely due to the fact that the comparatively short life of metal bearings in such installations led to systematic research being conducted with a view to finding a more satisfactory material. In the course of these researches synthetic resin bearings were tested and found to be more satisfactory than materials which had been used previously. It was found that these bearings not only had a longer life, but were more economical to run, their low frictional losses resulting in savings in power consumption amounting to as much as 25 to 30 per cent.

Plastic bearings have also been used with marked success for ships propeller bearings where the more usual lignum vitæ has been superseded.

The automobile industry has also made use of this type of bearings for such applications as steering gear bushings and the spherical bearings used in the drag link mechanism. Thrust washers on the front wheel pivots, and bearings for the distributor shaft have also been used with marked success.

The aircraft industry has developed an ingenious spherical self-aligning bearing in which the plastic material is moulded " in situ," and the running clearance is obtained from the shrinkage which takes place during the moulding process.

In Germany just prior to the outbreak of war tests were carried out on bearings made by winding resin impregnated tape round the finished shaft. The tape was wound on to a thickness of some 0.020 in. and was cured in position by means of suitable clamps. After curing, the outside skin was machined off and the whole soaked in oil which resulted in a swelling of the thin plastic tube, thus providing the necessary running clearance. Bearings of this type have shown very promising results on test, and it would appear that this is a subject upon which profitable development work could be carried out.

The Borough Polytechnic

We offer our heartiest congratulations to the Borough Polytechnic, which this month celebrates its jubilee. It was one of the first of our educational centres to realize the importance of plastics and to institute a plastics department. Under Dr. Redfern this section of the Polytechnic's activities has become famous throughout the country.

Started in 1892 for the promotion of industrial skill and handicraft, a technical school for boys was opened in 1897, and with the introduction of the 1902 Education Act the governors reorganized the school on definitely technical lines. It has become a model on which most Junior Technical Schools have since been established.

Since then the Polytechnic has been the pioneer institution for the nation-wide establishment of classes in laundrywork, ladies' tailoring, embroidery, cookery, heating and ventilating, engineering, plastics, nitrocellulose finishes and dental mechanics. The Polytechnic now turns out 6,000 students a year. Many of the workers in the factories and at the draughtsman's boards to-day, designing new aircraft or producing the fighting equipment for the second front, found their " industrial " feet in the Polytechnic.

South-west Essex Technical College

There will be a winter course on Plastics held at this college in Walthamstow until further notice. This follows as a result of the successful session held during the past summer. The lecturer is Dr. Wearmouth (British Xylonite Co., Ltd.). Applications to attend the lectures (the fee for the course is 15 shillings) should be made to the Head of the Science Department, at Forest Road, Walthamstow, London, E.17.

E

Valves in Polyvinyl Chloride

An account by Klant ("Kunststoffe," 1942/32/41) of the Evolution of Plastic-valve Design for Chemical Plant. Embodied in the Translation are Apposite Illustrations from "Technische Rundschau," January 7, 1942

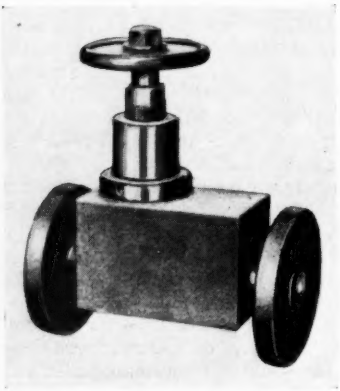


Fig. 1.—Rectangular-type valve in "Vinidur," according to German specification NW20. This type is machined from block material.

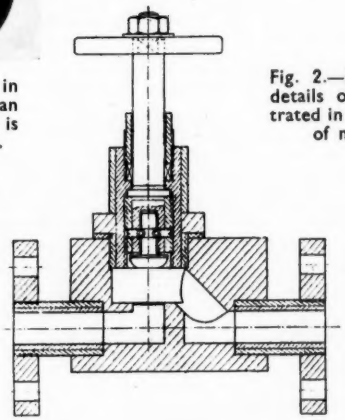


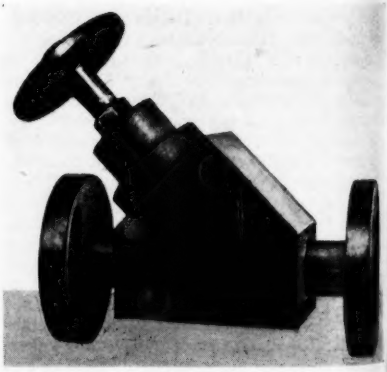
Fig. 2.—Elevation showing details of the valve illustrated in Fig. 1. Note bulk of material used.

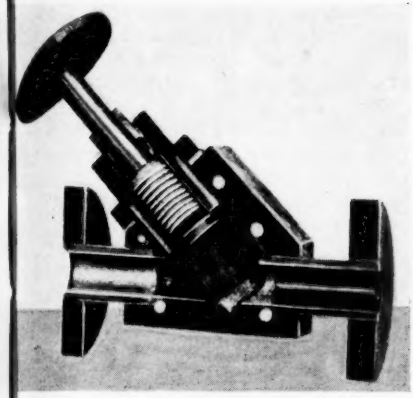
Fig. 3.—Sloping-type "Vinidur" valve, according to German specification NW25. Here the body is constructed in two parts bolted together.

As a result of the increasing use of polyvinyl chloride tubes (Igelit, PCU, hard) originally introduced on to the market under the name of "Vinidur," for corrosion-resisting purposes, there arose, at quite an early date, a demand for auxiliary fittings in the same plastic base.

The use of polyvinyl chloride tubes implies a considerable saving in weight, as the specific gravity of Vinidur is 1.4. As a rider to this, the use of metal valves with plastic tubes infers that the latter become very heavily loaded, and hence, in such circumstances, require special supports.

In the development of polyvinyl chloride valves, which have achieved very great success during the past few years, it is interesting to note the important part played by welding and hot forming—techniques at one time unique to metals amongst structural materials.





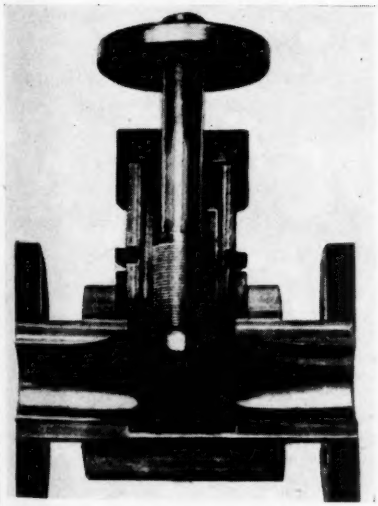
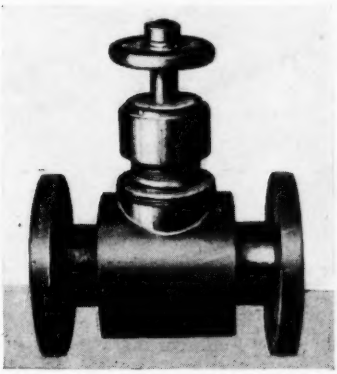


Fig. 4 (left).—Section of valve shown in Fig. 3. Fig. 5 (below).—Valve according to specification NW 40, built up from Vinidur tube. Fig. 6 (at left, below).—Section of valve shown in Fig. 5.



Valve Bodies Machined from Block Material

In Figs. 1 to 4 is shown the construction of valves in this resin, full views and sections being given. The most noteworthy feature of their design is the production by machining of the most important parts which, especially in the case of the body of the valve, are produced from solid blocks.

The strength, however, of pressed blocks is considerably influenced by the presence of internal stresses. Such valves, therefore, designed to meet the loads specified for "Vinidur" tubes, become unwieldy in construction, more particularly in respect of the body of the valve. The tube itself, for example, may have to stand a pressure of six atmospheres at 40 degrees C. (Figs. 1 and 2).

Moreover, as the thickness of the blocks required could not always be met because of difficulties of production, recourse had sometimes to be made to the use of two blocks suitably joined together. In such a case the contacting faces of the blocks were accurately machined, joining being effected by means of an adhesive. The required strength of the complete unit was then finally attained by the use of countersunk screws, the ends of which were covered by means of "Vinidur" plugs. (Figs. 3 and 4). The seat and thread for the junction of the upper and lower parts of the valve were machined from the complete block.

What might be termed the superstructure of the valve, stuffing box and spindle bearings, for example, were similarly constructed, various elements being joined to each other by adhesives,

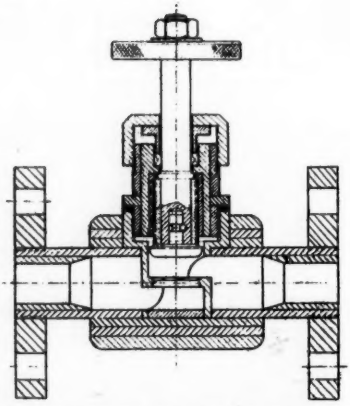


Fig. 7.—Section of Vinidur valve to NW20, showing method of building up from tube.

and consisting in part of machined components cut from the solid block and part from tube. The spindle of the valve was machined from rod and carries a sleeve fixed to it by means of adhesive. On this sleeve is machined the thread. The method of attaching the valve facing will be seen from Figs. 2 and 4.

The valve support consists of two tubes driven together and cemented. The outer of these is provided with a thread for screwing on a Vinidur flange.

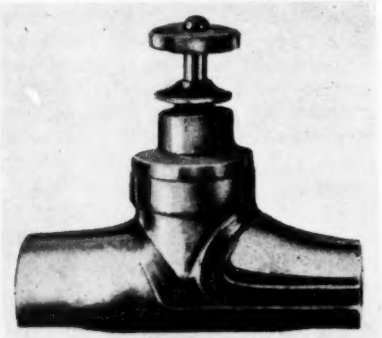


Fig. 8.—Rectangular valve, according to NW50, showing construction from simple tube with assembly by welding.

Valves of this type found extensive use in connection with Vinidur pipe lines such as that shown in Fig. 5. This method of construction, however, left much to be desired. For example, the large mass of very expensive raw material which had to be used considerably increased production cost, which was further raised by the large amount of machining and hand work required. Moreover, the form of valves of this type was not in accordance with the best dictates of hydraulics. Finally, a primary objective, namely, the saving of weight, was certainly not fully achieved.

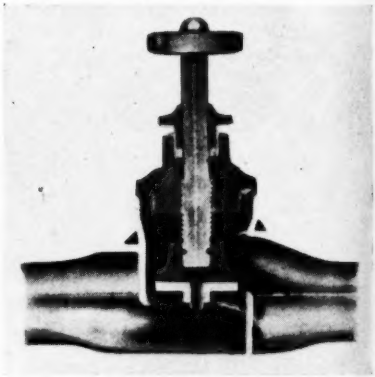


Fig. 9 (above).—Section of rectangular valve to NW50, corresponding to complete view shown in Fig. 8.

Valve Bodies Consisting of One or More Superposed Tubes

In Figs. 5 to 7 are shown attempts to exploit in practice the superior strength of Vinidur tubes as opposed to the material in block form. It will be seen that the body of the valves consists of a number of standard Vinidur tubes drawn one over the other and fixed by means of adhesive. This system possesses the advantage of employing readily accessible semi-manufactured forms and at the same time enables loaded parts to be reduced in section. Economy in raw material is effected, and the necessity for machining is also reduced.

Generally it was found necessary to provide for the valve seat and the thread of the screw-down portion of the upper part of the valve, a special insert cut from solid material. This was, in turn, provided with holes for reinforcement on the input and output side. The construction of the outer part of the valve and its supports resembles that developed for valves machined from solid blocks. By boring out the input and output sides of the valve to conical form better throughput of fluid was achieved.

From the standpoint of weight, however, this system of construction was still not entirely free from drawbacks. Hydraulically, the upright form of the valve possessed inherent disadvantages and has now largely been displaced.

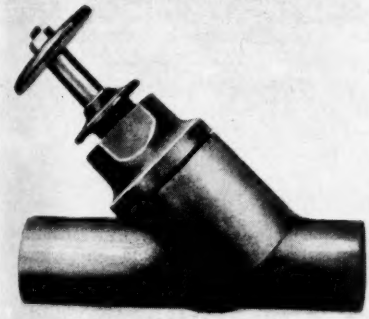


Fig. 10.—Sloping-type "Vinidur" valve to NW 40 "single tube construction," body assembled by welding (see Fig. 11).

Welded Valves

As the maximum loads on Vinidur valves used in conjunction with Vinidur pipe-lines cannot, in general, exceed those imposed on the pipe-lines themselves, it was considered that a part of the tube forming the pipe-line might be adapted with practically no modification to form the lower part of the valve body. In this way very considerable economy in material and in production time could be effected.

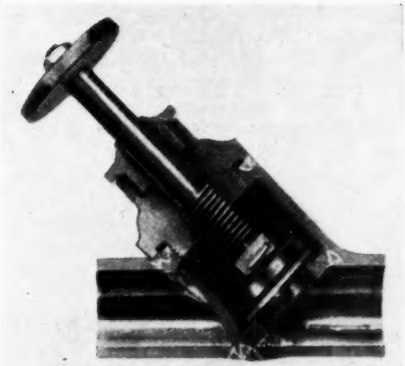


Fig. 11.—Sectional view of valve shown in Fig. 10. This view illustrates great economy effected in material by rational design.

It was not possible, however, to realize this scheme in practice by the use of the adhesive technique, as this type of joining required not only accurately finished faces, but also relatively large areas of joining surface in order that satisfactory junctions might be achieved.

Real lightweight construction first became possible with the advent of a welding technique used in conjunction with hot forming processes. Figs. 9 to 12 show steps in the development of such valves, both in the rectangular and sloping form.

These are of pure welded construction, the lower part of the body consisting of a single tube, whilst the spindle mounting

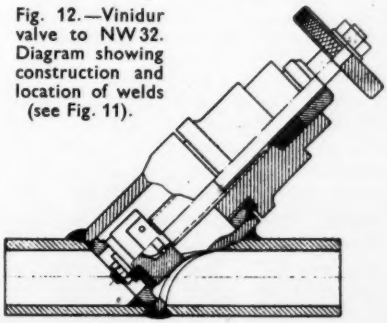


Fig. 12.—Vinidur valve to NW 32. Diagram showing construction and location of welds (see Fig. 11).

is machined from a heavy semi-manufactured form (block or rod) which, in the case of the larger sizes, consists of two blocks welded together. An accompanying line drawing will serve to make clear the welding system employed and show how the upper portion of the valve is joined to the tubular lower part of the housing.

The provision of a soft packing piece assures consistent fluid tightness. It limits, however, the use of such a valve

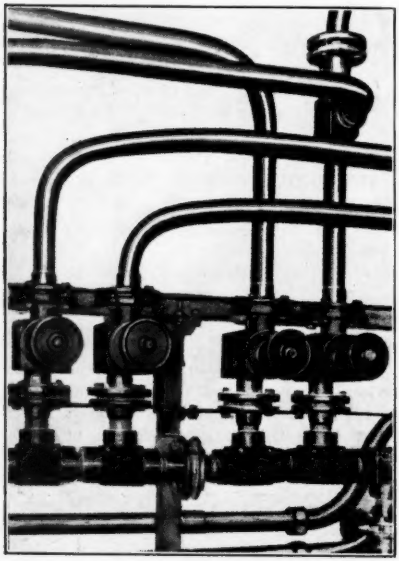


Fig. 13.—Pipeline battery showing Vinidur conduits used in conjunction with Vinidur valves of early type (block) construction.

to cases in which the packing material (soft Igelit packing or Buna) is not affected by contact with the chemicals carried by the valve. Official specification permits these valves for use up to nominal working pressures of six atmospheres.

By the use of bent sheet, welded to make tubes, in place of the standard tubes normally used for the purpose described,

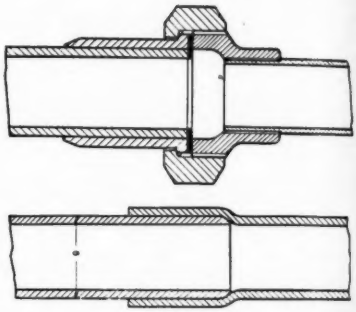


Fig. 14 (upper illustration).—Method of joining Vinidur tube (left) to metal tube (right). Lower illustration, slip-on joint between two Vinidur tubes; fixing is by means of adhesive (joint not dismountable).

higher pressures can be catered for and valves may also be made of larger size.

Valves of this type, both in the rectangular and sloping form, have been in wide use for some time and have been obtainable on the market as standard fittings. They are purchased with the tubular housing in a plain form and may thus be joined in any way required, using either adhesives or welding for the attachment of the necessary flanges. They may also be directly welded into existing pipe lines.

(To be continued)

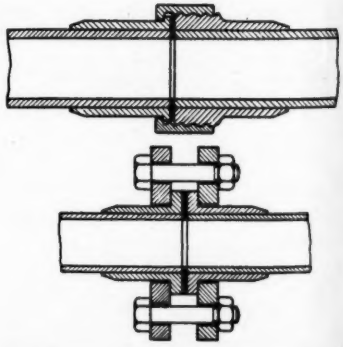


Fig. 15.—Union and flanged joints in Vinidur tubes (joint can be dismountable).

LIGNIN—A Plastic from Wood

The author continues his notes (see June, 1942) on the utilization of lignin for making plastic mouldings and sheets. Of great interest is the description of the so-called "explosion" process of the Masonite Corporation

By JULIUS GRANT, M.Sc., Ph.D.

IT will have been realized by now that, although lignin is essentially a plastic in its own right, its plastic properties are enhanced by the presence of other substances which need not necessarily be plastics themselves. Thus, the use of aniline during the process for the isolation of the lignin from the wood has been referred to[10] (June issue), but it may also be used for a secondary treatment following the isolation of the lignin by acid hydrolysis. Certain phenols and alcohols behave similarly to aniline; thus, phenol in benzene solution (H. Burmeister[18]) or phenol and sulphuric acid in an aqueous medium have both been used with success, while M. Phillips and M. J. Goss[19] have prepared a mouldable product by the direct treatment of wood meal in the presence of an acid catalyst. The tanning properties of lignin may also be mentioned, since it is probable that they have a common origin (from the point of view of chemical structure) as the moulding properties.

Yet another Mead Corporation patent[20] describes how mouldable boards may be produced by mixing fibrous material (e.g., cotton linters, α-cellulose, mechanical wood, asbestos or pyrophyllite) with finely divided lignin matter in 97 per cent. of water, with agitation, and forming the mixture (e.g., on a wire, so that the water is withdrawn by suction) into a board of desired form and thickness, which is dried at a low temperature. Synthetic resins of the urea- or phenol-formaldehyde type, pigments, dyestuffs or sizing agents may be added at the beating or mixing stage. The dried boards are subsequently moulded at a pressure of 10,000 lb. per sq. in. and 154 degrees to 177 degrees C. It is interesting to note that the fusion-point of the lignin may be varied by means of controlled additions of furfuraldehyde.

Another interesting development of a similar nature, but based on the use of sulphite waste liquor, is reported[21] from Rothschild, Wisconsin, where the Marathon Paper Mills Co. has recently started up a $150,000 plant having an output of 25 tons per day, and building accommodation for doubling this. The process comprises essentially the cooking of wood chips under pressure in an alkaline liquor recovered from sulphite waste liquor. Full details are not available, but it appears that this liquor is a by-product from the manufacture of vanillin from sulphite waste liquor (cf. Howard,[13]), since such a plant, as well as a sulphite liquor treatment plant, adjoins the new works.

Marathon Process

The result of this cooking operation is a pulp which is rich in lignin, and can be formed into flat sheets or rolls on a paper machine; the former may be laminated together under pressure, so as to form a strong, dense and water-resistant composite mass. Alternatively, the sheets may be pressed in moulds of desired shape; or the pulp may be de-watered, dried and ground, and used as a moulding powder. The material is thermoplastic, but not thermosetting, although this property is obtainable if desired by adding appropriate auxiliary constituents; curing reactions are, however, unnecessary, and the usual moulding conditions of tem-

perature, pressure and time are found to be suitable. An important limitation of the resulting material (which is shared to various degrees by most other lignin plastics) is its colour, since this is brown before moulding and dark brown to black after this operation. This relegates such products essentially to the rôle of a " core " material, but as such it has the qualities of low cost and good strength, and, of course, it can be surfaced or laminated with sheets of desired colours or surface-treated with coating resins.

The Production of Colour in Lignin Plastics

There are, however, indications that this problem of colour is not an insuperable one. For instance, the Masonite Corporation has attacked it, and a patent[22] in the names of H. W. Morgan and B. O. Stewart claims a solution. It is concerned, however, not so much with the natural colour of the lignin as with the darkening in colour which occurs during the explosion method of fibre disintegration described below. This they attribute to the formation of pyroligneous acid (final pH value, 3 to 4), and it may be avoided by previously passing the wood (in small pieces on a conveyor) through three baths containing, respectively, a boiling 5 to 15 per cent. sodium sulphite solution, the same solution at 20 degrees C., and water, the period of immersion being 2 mins. in each case.

In conclusion it is desirable to refer to a type of product which is very closely allied to some of those mentioned above, and which although it does not consist of lignin alone, owes its more important properties to that substance. It is logical to argue that in the manufacture of mouldable products from mixtures of fibrous materials and lignin one is merely reproducing again the conditions established originally by Nature in the tree; why not, therefore, go straight from the wood to the desired mixture? The answer is that this may be rendered difficult by the likelihood that during the separation of the intimately associated lignin and cellulose the essential characteristics of one or the other (or of both) may be destroyed.

Masonite " Explosion " Process

Processes do, however, exist for this purpose, and one of the best known is the so-called " explosion " method, which is used in the production of Masonite, the constructional board made by the Masonite Corporation. In brief, the procedure (as described by J. N. Stephenson[23]) is to subject wood chips to a steam pressure of about 1,000 lb. per sq. in. in a special type of autoclave which behaves substantially as a gun; a valve is then opened so that the pressure is suddenly released, and the wood chips disintegrate into the fibrous state with explosive force, although, of course, the fibres retain much of their more closely associated lignin. The fibres may then be diluted with water and refined and screened, and formed into a web on a paper machine of the Fourdrinier type. The resulting wet sheets then are " moulded " by heat (at about 200 degrees C.) and pressure (e.g., 1,000 to 4,000 lb. per sq. in.), when they set to a hard mass. In a recent patent[24] by W. H. Mason of the Masonite Corporation a grainless, hard, strong board of high dry-strength and wet-strength is made by felting together the exploded fibres (after treatment with a waterproofing agent, such as petrolatum, if desired), drying them, and heating the resulting sheet for 15 to 20 mins. at 200 lb. per sq. in. pressure and about 149 degrees C. in a platen press with chromium-plated faces.

R. M. Boehm's theory of what happens[25] is that during the " explosion " process acidic substances are formed from the wood, and facilitate the rupture of the lignin-carbohydrate linkages by a form of hydrolysis; the fibres are subsequently re-formed by a reversal of this process, but, of course, into the shape of a board. It is claimed that, as a consequence, the fibres in the board are bound together in the same way as in wood, and that the properties of high strength in both the wet and dry states are thereby obtained as distinct from the low wet strength characteristic of the type of

fibre-bonding which takes place in paper manufacture (cf. J. Grant[3, 26]). It is an interesting fact, however, that these boards cannot be defibred and re-made again; this is probably because in the drying process a certain critical temperature has been exceeded, only above which a momentarily high pressure will suffice to bond the lignin.

In a process of an allied nature which has been worked out in the U.S.S.R. by M. Bogdanov and others[17] the explosion process is eliminated and much lower temperatures are used. Thus, pine wood sawdust is heated with 1.5 times its weight of water for 2 hrs. at 170 degrees C. and 115 lb. pressure, and the resulting powder may then be dried and moulded in forms under a pressure of 10,000 lb. per sq. in. at 220 to 250 degrees C.; phenol or glucose is added to increase the flowability where figured articles have to be moulded. The product obtained is known as " Barkalite." As already mentioned, the hydrolysis of wood by acid (e.g., by 3 per cent. sulphuric acid at 120 lb. per sq. in. for 45 mins.) may be also used for the preparation of a plastic material directly from the wood.

Low and High Density Plastics

A wide range of products is obtainable by the Masonite process and its modifications, particularly in respect of specific gravity. Thus at the one extreme there is " Cellufoam " having a density of only 1 lb. per cubic ft., and at the other is " Benalite," the density of which exceeds 90 lb. per cubic ft. A " Cellufoam " board 4 sq. ft. in area and 1 in. thick weighs less than half a pound, whereas a half-pound block of " Benalite " of the same thickness has an area of only 8 sq. ins. This range of specific gravities is about 10 times greater than that obtainable from the natural woods. The strengths of these products are roughly proportional to their specific gravities, being of the order of 6 lb. and 4,000 lb. per sq. in., respectively. Between these two extremes is, of course, a wide range of boards of intermediate properties which are used as insulators, constructional materials, etc.; " Benalite " has many of the properties of a laminated phenol plastic (R. M. Boehm[28]), and it corresponds with the maximum possible density of lignin. It should be pointed out that " Cellufoam " is not a true lignin product in the sense that lignin is the binding constituent. Its extreme lightness (and in fact it is claimed to be the lightest possible wood product) is due to the addition of a foaming agent to a suspension of kraft cellulose fibres; the resulting foam is formed into a web on a Fourdrinier wire, and dried at a high temperature so that the water is removed rapidly by evaporation, and the " skeleton " of the foam sets to a mass which has high sound- and heat-insulating properties.

Porous structures of low specific gravity have also been made by the addition of substances which react to produce a gas under the conditions of manufacture. Thus, S. Schless[29] has suggested the addition of aluminium powder to an alkaline fibrous composite after it has been formed into a sheet. This sheet is then moistened and placed between two plane surfaces at a distance apart equal to the thickness desired for the final board; the alkali then reacts with the aluminium to liberate hydrogen, and the sheet is " blown out " as a porous mass until it reaches the desired thickness.

Finally, it is evident that while lignin as a plastic has certain limitations, yet the wide range of purposes for which it can be used and the abundance of raw material available for its manufacture amply justify the consideration of it as a future and possibly important member of the plastics family.

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(18) *U.S. Pat.*, 2,192,030, 27.2.40. **(19)** *U.S. Pat.*, 2,190,909, 20.2.40. **(20)** *Brit. Pat.*, 482,894, 6.4.38. **(21)** *Paper Trade Jour.*, 1939, 109, *(22)*, 90. **(22)** *U.S. Pat.*, 2,234,188, 11.3.41. **(23)** *Pulp and Paper Mag. Canada*, 1940, 41, 485. **(24)** *U.S. Pat.*, 2,234,126, 4.3.41. **(25)** *T.A.P.P.I. Papers*, 1940, 23, 387. **(26)** *PLASTICS*, 1940, 4, 146. **(27)** *Proc. Tech. Sect. Canadian Pulp and Paper Assoc.*, 1941, 27, 23. **(28)** *Paper Trade Jour.*, 1940, 110, *T.A.P.P.I. Sect.*, 249. **(29)** *U.S. Pat.*, 2,235,176, 18.3.41.

World's Industry Employs Plastics

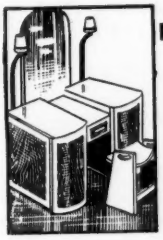
GENERAL ENGINEERING

Gears in laminated plastics still present problems to be solved. For the past 20 years they have been employed as standard for the timing train in internal - combustion engines; they are now finding an extended field of utility in other industries. Research on the Continent seems to be influenced by the desire to replace textile fillers by cellulose-wool fillers, and considerable interest centres on the development of gears of laminated beech. Opitz and Blasberg (Deutsche Kraftfahrforschung) indicate that laminated materials with cellulose-textile fillers show greater wearing power. In compressed wood gears, film glue is shown to be superior to liquid glue. Coarse textile fillers exhibit greater wear resistance than finer textile fillers. Kraemer, in " Kunststoffe," has indicated that the former possesses better damping properties. In fixing such gears to metal bushes pressure should not be greater than 1,700 lb. per sq. in., whilst if a gear be expected to operate in two directions, two feather keys should be provided. Such gears must always work in conjunction with metal gears; cast iron or steel are preferred. The widths of mating gears should be the same. Good lubrication is essential. At low speeds high viscosity is required, and at high speeds low viscosity gives better results. Pitting at the pitch line can be cured by the use of high viscosity lubricants. The breakdown strength of the oil would ideally, it appears, be equal to the endurance strength of the plastic. **Laminated plastic gears** may possibly replace heavy duty metal gears. Kraemer has reported a special case for a slow-running gear subject to impact loading and laminated plastics proved better in this case than bronze gears. In general the merits of the material must be judged precisely in accordance with design and service requirements. An important point in using laminated phenolic gears is noted by Opitz and Blasberg in that after a given running-in period, the wear of such gears becomes a linear function of time, whilst wear increases exponentially with load. **World's largest plate rolls.** A four-high mill constructed by Demag is provided with plastic roll-neck bearings for the supporting and working rolls. The bearing diameters are 1,050 and 770 mm. diam. respectively. The mechanical turnover device for the sheet is fitted with 500-300 mm. diam. plastic bearings. The mill is designed to handle plates up to 165 tons in weight. Working rolls are 1,100 mm. diam., supporting rolls 1,600 mm. diam., and are about 5,200 mm. long. Plastics are also used as skid surfaces in the roll-changing mechanism and for the screw-down worm wheel. " Kunststoffe " for August, 1942, contains a detailed account by Arens of the construction of this mill together with working drawings. The bearings, built up of laminated fabric-base plastic, are designed to withstand a roll pressure up to 3,000 tons. They are pressure lubricated by grease and are water cooled. Several months' operation has demonstrated the entire satisfaction of plastics for heavy-duty bearings on this mill. **Importance of accurate design for roll-neck bearings** in plastics is emphasized by Meurer (" Stahl und Eisen," 1941/61/13). The author refers to water lubrication and to the importance of additions of corrosion-inhibiting emulsions. **Plexiglass shields for use on machine tools** are discussed in " Zbl. Gew. Hyg.," 1941/38/137. These are attached to a single

arm holder with several adjustable members in order to allow direct attachment to moving parts of the machine. For high-speed lathes and milling machines and for wood-working machinery they provide very good protection against chips and swarf.

TEXTILES

Surface treatment of artificial leather is described by Eszer in "Kunststoffe" for August, 1942, p. 243. The author points out that not only is it desirable from the sales angle to make the artificial product resemble natural leather, but that this is sometimes technically advantageous. Graining is done with suitably engraved plates in a press, or with engraved steel rolls in a calender. The press method sometimes leads to streakiness, particularly in coloured leathers, and the use of calenders is, in general, to be preferred. For certain special effects presses must be used, however. Pressures of 5-100 tons may be required for this work, according to the class of design required; the lighter pressures being obtained by levers, heavier loads by means of hydraulic pressure. A mean through-put speed of 3.5 m./min. is general in the case of the calenders; the precise speed chosen, however, depending on design and effect required. Stepless control of speed is desired and temperature control is also an advantage. The rolls may be heated to 30-120 degrees C., according to the nature of the work. Water cooling in conjunction with steam heating may also be necessary. **Leather substitute on polyvinyl-chloride base** is among the developments treated by Mienies in "Kunststoffe," 1942/x/35. The author deals also with other aspects of the development of this material and describes also the "igamid" injection moulding resins made by the I.G.



FURNITURE

Rubberlike synthetic resin, the composition of which is not stated, is said recently to have been produced in Italy and to have been successfully used as a floor-covering. Extensions in its application are visualized for the replacement of natural rubber and certain other types of synthetic rubber. It would appear also to possess some value as a corrosion-resistant coating for metal, and attempts are being made to employ it in the place of tin on sheet iron for cans for food preservation.

MISCELLANEOUS

Silver-bearing resin surfaces possessing self-sterilizing properties are produced by combining silver with certain types of plastic base, either by direct dissolution of the silver salt in the base, the dispersion of silver compounds in the unpolymerized or partially polymerized resin, or in the plasticizer used in conjunction with it. It appears also possible that silver might be combined with the filler if such were used. The complex formed is intended to be applied by brush, spray or impregnation to suitable bases, such as glass, wood, paper, cloth or plastics themselves, hardening being by polymerization or solvent evaporation. Goetz, in "Science" for May 22, 1942, describes the theory and practice of such self-sterilizing surfaces. It appears that considerable mechanical strength has been achieved, the films standing up to long and arduous use and being, at the same time, immune against attack by hot water and weak acids and alkalis such as might reasonably be expected to come into contact with them.

To be of value a minimum silver content is required; 1 gram of silver per 1,000 sq. cm. of surface being sufficient for the heaviest type of duty so far developed. The treated surfaces do not lose their activity under normal conditions of storage. **Acetate sheet and wire reinforcement** is advocated by Monsanto Chemical Co. (Plastics Division) as a glass substitute to guard against danger of shatter through bomb blast and impact. It is pointed out that it may be drawn or formed into special shapes and can be fitted to any normal wood or metal window sash. An account in the July issue of "Modern Plastics" states that this material does not burst under "shock vacuum" of 28 ins. mercury. Window glass imploded at 15 ins.; coated glass withstood 22 ins., whilst heavy-gauge wire-reinforced glass imploded at 26 ins. Reinforced acetate withstood 2-lb. ball dropped from a height of 42 ins. before penetration was effected; there was no shattering. **Spray jets for fire-fighting** purposes have been produced in Tenite and moulded by Northern Industrial Chemical Co. and Niagara Insul-Bake Speciality Co. Inc. for Mul-T-Jet Nozzle Corp. Importance is attached to the shatterproof quality of the cellulose acetate from which these parts are moulded, of their rust and corrosion resistance, their light weight, easy detachability and high bursting strength. It is said that already they have been widely adopted for industrial fire-fighting plant and for hand-operated equipment in fire-fighting organizations. **Strength at elevated temperature** of phenolic resins was dealt with by Carswell, Telfair and Haslanger in a paper presented before the A.S.T.M., June 23, 1942. It was determined that, between −51 C. and + 71 C., mechanical strength of moulded phenolics varied between ± 15 per cent. for values at 25 degrees C. Tensile and bending strength decrease with increasing temperature, although, in the case of high impact-strength materials, shock resistance increases with increasing temperatures. Tensile properties, somewhat surprisingly, are practically independent of the filler used, although it is pointed out that impact strength may be greatly increased over the entire range of testing temperatures by the use of fibrous fillers. It is noted that, in contrast to thermoplastics, the effect of temperature on thermosetting resin plastics is relatively slight. **Summary of theory and practice of application of synthetics in the paint and lac industries** is presented in "Technische Rundschau" for June 12, 1942. Statistical data as to production and consumption of synthetic resins is given and some comparative observations are made upon the advantages of synthetics as opposed to natural gums. **National Defence Orders in U.S.A.** now include a comprehensive list (thermoplastics order M-154) issued on June 27. This list summarizes industrial processes and requirements in the light of thermoplastic production and consumption, the latter being given in order of priority. The list is of interest apart from the purpose immediately served, insofar as it indicates the immense field of applicability of thermoplastics. **Transparent tanks** made of cellulose acetate or other sheet plastic have been used for some time past for holding the de-icing fluid (generally ethylene glycol) on some of our larger aircraft. A description was included in a recent issue of "The Aeroplane," which gave details of the fitting of the tank in the Avro Lancaster, our largest bomber. These tanks are slung behind the front space in each inner nacelle. They are formed together from two shaped halves and are fitted with inlet and outlet threaded caps. Examples of these were shown at a recent exhibition in London. The capacity is about 1-2 gallons. **Laminated constructions** with resin impregnation will assume even larger proportions in the fields of building of all types with the formation of a new company in this country under the name of Wood Development, Ltd., which will carry out research work on veneers and other types of constructions made with a wood base. The formation is especially interesting since it is in a sense an amalgamation of forces, which include Flexwood Plywood Industries, Venesta, Ltd., Saro Laminated Wood Products and Tyne Plywood Works. All these companies are represented on the board.

INQUIRIES AND ANSWERS

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. Unless otherwise stipulated, it is understood that the submission of a problem to the Editor permits its publication in this journal.

Truck Tyres

We have read with interest your July issue, page 221, of the fitting of plastic wheels to Lewis Shepherd's hoist trucks.

We in this factory are using electric trucks, and we are finding that the rubber tyres have a comparatively short life due to metal cuttings on the floor, and we are anxious to find a substitute material for these tyres.

We would be very interested if you could put us in touch with makers of a suitable material.

THE METAL BOX CO., LTD.

[EDITOR'S NOTE.—Presumably the inquirer does not mean a substitute similar to rubber since, doubtless, this would have no longer life than the rubber tyres against metal cuttings. It is possible that the plastic wheels moulded from resin impregnated fabric that were available in pre-war days would serve the purpose. We remember such wheels were on exhibition at the offices of Bakelite, Ltd., to whom inquiries might be addressed.]

Presses for Plastics

Your article in the September issue on "Presses for Plastics," taken from V.D.I. Zeitschrift, by Hubert Von Hullen, is very interesting indeed, as it shows that the German development is very much in line with our own.

It would appear that the Germans go in for power presses a great deal more than we do, but I feel that the follow-up effect which is obtained by means of the hydraulic press cannot be equalled in any way on a power press.

There appear to be two errors in translation. One, with regard to the fluid pressure, you state that it is limited to about 12/20 tons per sq. in. and imagine you mean 1 to 2 tons per sq. in., because later on in the article the pressures are mentioned as low pressure up to 225 lb. per sq. in. for quick approach and high pressure at 2,800/4,500 lb. per sq. in.

I was particularly interested in the remarks about the applied loads not being unduly high and the deformation of the structure of the press. This is a point which I tried to bring out in my paper which I read in Birmingham, because on sheeting presses and injection moulding presses, the press must be designed more by the deformation than by stress principles.

I think there is a mistake in the translation when you refer to "elastic age" on page 298 and that this should read "elastic limit." I believe the German for "elastic limit" is "elastizitaetsgrenze."

May I congratulate you on getting hold of this article at the present time.

Stroud. J. L. DANIELS.

[EDITOR'S NOTE.—Mr. Daniels is quite correct, for the German article referred to pressures of 300 and 600 Kg/cm.^{2} The words "elastic age" were typographical errors for elastic stage.]

Rubber Latex Bowls

With regard to the paragraph in the August issue of "Plastics" suggesting that latex bowls should be made in plastics, it may interest you to know that we were approached by the United Africa Co., Ltd., as early as December, 1940, and we actually received our first order from them for moulded latex cups in Beetle Standard White in January, 1941, and we have been supplying them fairly regularly since.

These bowls are 4 ins. diameter at the top and 2¼ ins. deep inside, almost semi-spherical except for a flat base about 2 ins. across. These measurements are only approximate.

THE STREETLY MANUFACTURING CO., LTD.

FILLERS FOR PLASTICS *(Contd.)*

Information regarding the effect of fillers on the properties of mouldings, etc., is essential to future development of the industry. In this continuation of his previous article the author now deals with the properties of mica, other mineral fillers and pigments

By
E. E. HALLS

Mica

MICA is of most interest as a filler in a finely powdered form. From the angle of incorporating it in moulding powders, it possesses two outstanding physical properties that must be observed, viz., it is non-absorbent and difficult to "wet." The additional operating care in production must be provided to overcome the difficulties consequent upon these unfortunate features. Usually other fillers are present with mica in phenolic moulding mixtures, owing to difficulties in incorporating it, and tendencies for it to peel in the moulded product if not initially incorporated efficiently. Mica moulding powders have earned a bad reputation for sticking to the mould, and, in common with most mineral-loaded materials, for producing marked abrasive wear upon tools.

Mica is usually used for electrical reasons, and hence choice of right grade of mica is warranted. That with conducting streaks, veins or particles should be avoided. Indian ruby mica is the highest grade, but is not essential. Some grades of mica contain included moisture, and, with

Table 17.—Summary of Data upon Mica.

	Muscovite group	Phlogopite group
Chemical formula	$H_2KAl_3(SiO_4)_3$	$HK(MgF)_3Mg_3Al(SiO_4)_3$
General name	Potash or white mica	Amber mica or magnesia mica
Chief source	India	Canada
Chemical analysis (typical) %:		
Silica	45.2	40.8
Alumina	38.4	26.9
Potash	11.8	12.7
Magnesia	—	7.6
Ferric oxide	—	12.0
Water	4.6	—
Specific gravity	2.75–3.0	2.75–2.85
Moh's hardness	2.8–3.2	2.5–2.7
Max. safe working temperature	500°C.	1,000°C.
Permittivity	4.2–5.0	2.9–3.0
Specific resistance, ohms $\times 10^{12}$	10–100	0.5–20
Electric strength, volts/mil at 20°C.	3,000–6,000	3,500–4,500
Loss of water % upon ignition at		
450°C.	0.03	Nil
650°C.	0.06	Nil
750°C.	1.69	Nil
800°C.	3.29	Nil
900°C.	4.20	0.20
1,100°C.	4.30	1.0 max.

special processing, are admirable for preparing powdered mica filler. This mica is heated rapidly to 1,000-1,100 degrees C., when the expansion due to expulsion of water leaves a very light mica, which easily pulverizes to a fine powder.

The two chief sources of reliable mica are India and Canada. The first of these supplies is the Muscovite or potash group of micas, chemically formulated $H_2K\,Al_3\,(SiO_4)_3$. This group has a specific gravity of 2.76 to 3.0 and resists temperatures to 500 degrees C. The second locality provides the phlogopite micas, chemically $HK\,(MgF)_3\,Mg_3(Al\,SiO_4)_3$. The specific gravity of these lies between 2.78 and 2.85. They can be safely used between 900 and 1,000 degrees C. Electrically, the muscovites have superior resistance, higher permittivity, and somewhat better breakdown strength. Either of them is admirably suited to incorporation in plastics, but where that little extra is required with respect to electrical characteristics, the muscovites are advocated. Further data upon the micas is compiled in Table No. 17.

Mica can satisfactorily be incorporated in shellac compositions, but greater difficulty is encountered with the phenolics. Mica-filled phenolics are, however, widely employed for electrical purposes.

Mineral Powder Fillers

Numerous naturally occurring inert mineral powders as well as the pigments of the paint industry are employed as fillers for plastics. These include powdered slate, the various silicas, clays, barium sulphate, zinc oxide, calcium carbonate, etc., etc.

Owing to the relatively non-absorbent nature of mineral fillers, fineness of particle is desirable, and the inclusion of grit or isolated larger pieces of extraneous origin is objectionable. Under fluctuating stresses of service, failure may originate by fracture at such points of non-homogeneity.

Slate powder is produced in a range of finenesses up to 300 mesh, and is made either from slate rock or from scrap in the form of broken slates. Specific gravity of slate powder is of the order of 2.75 to 2.80 which is reasonably low for a mineral filler. It exhibits some very small tendency to absorb water, absorption upon immersion of slate rock being of the order of 0.10 to 0.20 per cent. in 24 hours. It is inert and of permanent colour, and is inexpensive. Freedom from extraneous gritty material, from chalk or lime, and absence of oily material from the grinding are essentials. It is used in synthetic plastics as well as in rubbers and ebonites.

Diatomaceous earths are extensively employed in similar applications. Various origins are available. Actually these earths are the siliceous remains of the tiny organisms known as diatoms. They form white, mealy powders consisting of a very pure form of silica containing about 5 to 6 per cent. of water. Kieselguhr, infusorial earth and fossil flour are common names for these earths. They are light, somewhat absorbent despite their inorganic character, and thoroughly inert. They are used in phenolics, cold moulding compositions, thermoplastics and the rubbers. In the hard ebonites they are useful for giving improved electrical properties, and the rubber-base composite insulating materials utilize this class of filler to produce sheet, rod and tube material possessing a high degree of resistance to heat, as well as special electrical qualities of resistance to tracking and capability of withstanding the effects of high-frequency fields. Whyte and Lord in B.P. No. 384,694 claim the incorporation of up to 30 per cent. diatomaceous earth in synthetic resins and in cellulose ether and cellulose ester films without loss of transparency, this presumably being due to particle sizes of less than 0.01 mm. They also claim marked

improvement in resistance to cutting and to abrasion (and therefore special suitability for such commodities as gramophone records).

Silica flours produced chemically by the precipitation of silica from water-glass solutions with sulphuric acid, filtration and thorough washing of the precipitate, drying, igniting and grinding also have their use. In general, they are coarser, and more dense and granular than the natural siliceous earths.

The silicas are particularly acid resisting and, therefore, useful for loading phenolic moulding plastics for chemical plant, e.g., moulded pickling equipment, vats, baskets, cross-members, etc. Similarly they are suitable for inert cements, e.g., a valve-basing cement for rapid setting exhibits the following composition:—

Phenolic resin	...	27.5 per cent.
Silica flour	...	72.5 per cent.
		100.0 per cent.

Again, some of the siliceous earths show appreciable absorbency properties, and this suits them for the pale-coloured amino plastics in delicate and translucent shades.

Various clays are suitable as inert fillers. Most notable of these are the china clays ("Kaolin") originating in this country, and the Florida earths and Bentonite of American source. These are hydrated aluminium silicates, quarried, washed and graded to yield fine, soft, uniform white powders. Under the microscope, the clay particles reveal themselves as of irregular shape. This characteristic assists the incorporation with plastic and helps to offset the disadvantages they have in contrast to wood flour of not being absorbent and capable of being impregnated with the plastic. By virtue of the mode of preparation, viz., quarrying and water-washing, filtering and air drying, clays may contain much "loose" moisture, i.e., absorbed water that can be driven off by drying at 100 degrees C. as distinct from the combined water of hydration. This may rise as high as 8 per cent., and while of no detriment in paper-making industries, it must be removed by thorough drying before incorporation in plastics. The combined water of hydration is not driven off below approximately 500 degrees C., and for special purposes, e.g., plastics to withstand continuous working at elevated temperatures, ignited clays have advantages over the normal forms. Otherwise, the constituent elements are held in fast combination so that, apart from being inert and neutral, they are strongly resistant to chemicals including acids and alkalies. Test values on typical clays are given in Table No. 18. Similar clays containing

Table 18.—Compositional Data upon Typical Clays.

Sample No.	1	2	3
Composition %:			
Silica, SiO_2	46.21	46.60	46.46
Alumina, Al_2O_3 ..	39.82	38.26	37.40
Ferric Oxide, Fe_2O_3..	0.38	0.55	2.00
Lime, CaO	0.45	0.42	0.86
Magnesia, MgO ..	0.10	0.20	0.21
Potash, K_2O	0.23	0.57	1.26
Water, total	12.81	12.40	11.81
	100.00	100.00	100.00
Grit	0.09	0.32	2.2

a more or less proportion of the aluminium replaced by iron are likewise used where the brownish colour presents no objection. The iron clays are somewhat less acid resisting than the china clays. The specific gravities of the clays range from 2.5 to 2.8.

Similar to the aluminium clays are the hydrated magnesium silicates. These are of varying densities (2.6 to 2.9) and finenesses, but clean, white, inert and chemical resisting. The most outstanding is talc, french chalk, soapstone or steatite. This corresponds to the formula $Mg3H_2(SiO_3)4$. It is greasy or soapy to the

touch and rather more difficult to "wet" and incorporate in plastic mixes than are the clays. It has good acid resistance and withstands temperatures up to red heat before dehydration occurs. Meerschaum—$H_2MG_2(SiO_3)3$ H_2O—is a similar material.

These natural silicate materials all figure in mineral-loaded phenolics for heat-resisting applications and in special compositions for chemical ware, as well as in loaded rubbers and ebonites, in plastic cements and adhesives. They are also used in the bitumen and pitch-bonded plastics, and in "carbon" conductors and resistors which, pitch-bonded, are fired at high temperatures to hard masses. Some compositional data upon the latter are presented in Table No. 19.

Calcium sulphates are employed in one of their several forms. Plaster of Paris is the chief. This is produced from the natural rock, gypsum, $CaSO_4$ $2H_2O$, by grinding and calcining at 120 degrees C. whereby only 75 per cent. of the water of hydration is liberated. Its use is mainly confined to phenolic plastic cements of various types and bituminous bound moulding materials. Ignited above 160 degrees C. all the water is driven off and furthermore it is not readily reabsorbed. The average commercial material of this type shows a loss on ignition (moisture) of the order of 1 per cent. as against 21 per cent. for uncalcined gypsum or for the artificial hydrated calcium sulphates. The latter are known under various names, e.g., pearl hardening, pearl white, crown filler, pearl finish, alabastine, etc. They are formed by double decomposition of calcium chloride and sodium sulphate in aqueous solution, and particle size is dependent upon conditions of precipitation. Flat, table-like or needle-shaped crystals are the principal forms. All types lose about 21 per cent. due to water evolution upon heating to 160 degrees C.

Table 19.—Bituminous Plastic Mixtures for Firing to Electrical Components.

Number	1	2	3
Object	Resistors	Protector carbons	Electrode carbons
Composition % :			
Coal tar pitch, heavy	35	40	33
Petroleum coke, 200 mesh	10	50	—
Fine graphite.. ..	—	—	67
Lamp black	—	10	—
China clay	35	—	—
Siliceous earth ..	20	—	—
Peak firing temperature °C.	1,200	820	950

Specific gravity of all forms of calcium sulphate is of the order of 2.4.

Apart from uses in cements, the high water content of the calcium sulphates and its evolution at relatively low temperatures, renders it advisable to restrict the use of these materials to aqueous plastic masses, such as the casein plastics. Moreover, while inert to normal conditions of exposure, the calcium sulphates are not particularly acid resisting, e.g., they are poor against muriatic acid.

Pigments as Fillers and Colorants

All the foregoing mineral loading materials are in effect inert natural products. Another group of powders utilized comprise the pigments of the paint industry. In plastics they largely function as fillers, although they may also be used as colorants. Regarding the group as a whole, the requirements for plastics will be closely the same as for the paint industry. The powders must be clean, uniform, fine, of consistent grain size, free from extraneous matter, impurities, or adulteration. Those produced chemically, as distinct from those derived from natural sources, must be free from the reacting chemicals. They should thus be free from water-soluble salts, acids or alkalies. B.S.S.

No. 260 for barytes and No. 254 for zinc oxide are typical. The latter, for instance, calls for two types of purity, 99 and 96 per cent. zinc oxide respectively. Of interest to plastic manufacturers are:—The coarse particle requirement (all through 200 mesh), volatile matter at 95/98 degrees C. 0.5 per cent. max., water-soluble matter 0.25 per cent. max., and lead content 0.2 per cent. and 3 per cent. max. for the two types. A purity standard not lower than type 2 should be insisted upon, and material such as covered by the following report viewed with suspicion:—

Composition.

	%
Loss at 95/98 degrees (water)	1.3
Loss on ignition	9.0
Lead (as lead sulphate) ...	0.4
Iron oxide	2.8
Water soluble	0.7
Zinc oxide	85.8
	100.0
Reaction of water extract	Neutral.
Amout retained by 200 mesh sieve	33%

The material appeared to be dirty, the iron oxide figure reported above resulting chiefly from extraneous matter.

A glance at the several tables reveals many of the pigments employed. Barytes or barum sulphate is a dense crystalline white material, specific gravity 4.5. Either the natural material or the finer chemically precipitated barium sulphate is used. Barytes is generally only used for special purposes owing to its high specific gravity. Thus in shellac plastics for gramophone records, where a high density is sought, 15 to 20 per cent. of barytes, 15 to 20 per cent. siliceous earth, and 5 to 6 per cent. of carbon black is typical.

Closely similar to barium sulphate is lithopone, a mixture of barium sulphate and zinc sulphide, produced chemically by double decomposition of barium sulphide and zinc sulphate solutions. It offers advantages of being less dense and better obliterating. Zinc sulphide itself is used in some rubbers and ebonites, in particular as loading material for producing hard sheet products having special electrical properties with particular reference to power factor at high frequency (see Table No. 6, sample No. 13). Lithopone and aluminium oxide are useful for the same purpose although generally it is found not quite so good in the electrical characteristics just mentioned. Titanium oxide can be used as an expensive permanent white, but it figures in a special plastic ebonite or hard rubber, which, although "hard," is capable of compressing cold without rupture. For example, small tubular bushes can be expanded into position and to close dimensional tolerance by end pressure; materials of this type offer many advantages to manufacturers of light electrical components. Titanium dioxide is a suitable material when a pigment or filler is required in electrical rubber or ebonite having low power losses at high frequencies.

Zinc oxide is an extensively employed white pigment used in all plastics and a particularly popular filler for caseins and for rubbers. It is a chemically pure fine white powder, particle size being of the order of 0.0002 to 0.0005 in. Natural chalk, but more usually precipitated chalk, $CaCO_3$, is employed, principally in cheap bituminous bodies or in rubbers. It is whiter than the clays. Natural dolomite, a double carbonate of magnesium and calcium, $MgCo_3$, $CaCO_3$, is also employed. A much used white of recent years is aluminium oxide, Al_2O_3, particularly in thermoplastic moulding powders and in the amino materials. It is available in several grades of density dependent upon the mode of precipitation and the method of calcining. It is graded light, medium and heavy.

Mercury and antimony sulphides, at one time the recognized loading materials for "red" ebonites or hard red rubbers, are likewise used for pigmentation in phenolics to a limited extent. Reds and browns are also secured using one of the many oxides of iron pigments and, upon occasion, manganese dioxide. Ultramarine is used for blues. However, the majority of colours are obtained nowadays by means of appropriate plastic-soluble dyestuffs for translucent and transparent effects, or by means of the now many available groups of lake dyestuffs which can be used and incorporated in the same manner as mineral pigments or mineral fillers.

Stability of Pigments

Incorporated in plastic masses, the pigments briefly described can be regarded as reasonably stable under normal conditions. Their chemical composition must, however, be kept to the fore when deciding formulæ for specific conditions. Alkaline oxides, sulphides and carbonates react readily with acids. Thus zinc oxide, antimony and mercury sulphides, lithopone and zinc sulphides, and chalk are attacked even by weak acids. They should, therefore, not be included in acid-resisting products nor in plastics that are destined for service over longer periods in contact with faintly acid solutions or in acidic atmospheres. Even the iron oxides and some of the lower calcined aluminium oxides would fail against acid solutions.

Ground gas carbon and graphite are used, separately or together, in pitch bonded and subsequently fired, mouldings for electrical resistances, conductors and electrodes. Fine graphite is also included in phenolic moulding compositions as a lubricant and has special attributes in reducing wear on rubbing or moving elements. Up to date it has not been extensively employed, but it has a great potential field for gears, ratchets, pawls, etc. Moreover, where sheet and rod stock are machined for these components, the presence of graphite should materially assist cutting speeds and reduce wear on tools. Graphite, of course, is a shiny, soapy solid, having no absorptive properties, and therefore requires special attention in its incorporation. It has usually been employed in conjunction with wood flour, which assists in this direction. However, consideration might be given to the suitability of colloidal graphite, e.g., one of the Acheson "Dags," similar to oildag or aquadag. These products are now available in numerous media such as acetone and varnish, which would undoubtedly assist in the better distribution of a smaller quantity of graphite. Much work yet remains to be done in this direction.

Black mouldings are extensively employed for the principal electrical applications. The black coloration is secured by colorant over and above the normal filling agent. In the majority of cases a black dyestuff or lake pigment is used. This, however, is by no means universal practice and carbon blacks are also used, despite the possibility of electrical tracking or leakage. This theory held by some technologists is that the pigment, properly incorporated, becomes coated over the surface of each particle with plastic and so no loss of insulation results. Actually test results are misleading because, determined on standard test pieces, they are not discriminating enough and, in general, merely confirm the theory. The writer's view is that a colorant should be used of organic nature, soluble in the plastic, and the electrical values of the product established by test. If carbon black is used in a material like the phenolics, which are prone to track, it will hasten tracking once the latter begins to assert itself. Again, if inserts are positioned at close centres in mouldings, or if moulded stock is machined to thin sections, then local conglomerates of carbon may provide low resistance

paths and premature failure. In fact, this has been experienced in practice with black moulded phenolic rod of Continental origin. Small bushes machined from this regularly failed on megger testing, showing only a few megohms insulation at 500 VDC, whereas the stock itself failed to show the same fault until checked inside between points at close centres. Carbon blacks are extensively used in cellulose acetate mouldings for electrical purposes apparently satisfactorily. They can naturally be used in material destined for decorative or structural work.

A number of black fillers or pigments consisting mainly or entirely of organic carbon are on the market. They vary in nature according to origin and mode of formation or preparation, and consequently differ in particle size, "softness," intensity of colour and covering or obliterating capacity. The material derived from the incomplete combustion of gas, that is, from the natural gas of petroleum wells, has many attributes. It possesses a good velvety blackness and this, combined with its fine particle size, imparts high covering capacity. Several modes of preparation give slightly different grades. Not only is natural gas, but propane and benzole are also employed. In the channel process, the gas burns at specially tipped burners, impinging upon reciprocating channels above, from which the black is automatically scraped as it is formed. In the thermatomic process, the gas is cracked in preheated chequer-work brick furnaces. Another process decomposes the gas in high-tension electric arcs. Tar oils and heavy petroleum are similarly decomposed, using high-temperature processes. All such carbons are free from oily matter. Inferior lampblacks may contain oil, which must be guarded against, and may be comparatively greyish, due to larger grain size. Gas blacks marketed as satin gloss black, ebony black, jet black, channel black and thermatomic black, have average particle sizes between 0.1 and 0.15 microns; inferior blacks are not so uniform and range from 0.4 to 9.3 microns.

(To be continued.)

Plastics and Engineering

At a recent meeting of the Manchester Association of Engineers a paper on "Plastics and Their Application to Engineering" was read by Mr. J. Prior.

After a general talk on plastics, their composition and manufacture, the author discussed certain particular applications to the engineering industry, such as bearings, gears, wheel rims, covers and doors, etc. His reference to transparent plastics was interesting, for he recalled how he disliked equipping a machine with fabricated sheet metal guards, especially since, by warming and manipulation, transparent plastic sheets can be formed to curves corresponding nearer to the cast guard or to the pressing.

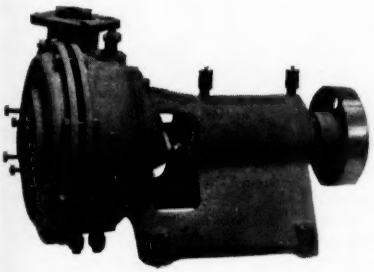
He also referred to the trouble of dry bearings and the attendant costly stoppages and replacements. The intelligent use of transparent plastics, alongside metal, using one or the other as inserts, could do much to obviate these worries by expanding considerably the age-old principle of "sight-feed" lubrication and the author firmly believes that it could be extended to grease as well as oil lubrication. Much can, he claimed, be done to ease the lot of the maintenance engineer, without altering either design or price. As for machine design, he stated that many parts of machines are not called upon to withstand any great stresses and are designed solely to be in keeping with the essential features. Assuming quantities are sufficient or that collective action can be taken, light brackets, filbows, angle pieces, guard supports, spacing collars and distance pieces for stationary or hand-moved spindles could all become more than possibilities either with or without metal pins and bushings, etc.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

NEW CENTRIFUGAL PUMP.—For the pumping of acids and other strongly corrosive liquids it is necessary to use pumps that are completely resistant to the conditions, which is important not only as regards wear and tear on the pump but also the elimination of contamination of the liquid.

The latest scientific principles in this field are well represented by the " Pulsometer-Doulton " stoneware centrifugal acid pump, a joint production of Messrs. Doulton and Co., Ltd., of Lambeth, and the Pulsometer Engineering Co., Ltd., of Reading (Berks). This special stoneware design has an external body and cover of cast iron, lined inside with Doulton acid-proof stoneware, cemented in, and is completely resistant to all acids (except hydrofluoric) and most alkalis. Three standard sizes of the pump are available, that is: 1¼-in., 2-in. and 3-in.,



and in the former case, for example, the suction branch is 1½-in. diameter, centrally in the cover, whilst the discharge is vertical and arranged to take 1¼-in., 1½-in. or 2-in. standard stoneware connections. The hood carrying the pump constitutes a rigid support both for the pump itself and for two substantial bearings carrying a large diameter shaft, ensuring freedom from vibration and distortion, whilst the casing is provided with an aperture, closed with stoneware cover, so that the pump can be drained.

As regards the impeller this is of the single inlet shrouded type, made in corundum specially hard stoneware, accurately ground and balanced to run without vibration, and securely fixed to the spindle. The boss of the impeller extends right through the stuffing box so as to protect the spindle, whilst specially designed vanes are provided to reduce the pressure on the packing to a minimum. Further, the stuffing box is of ample depth, provided with either a split vulcanite or a stoneware lantern ring with external connections through which water can be led to dilute any leakage discharging to the drain. If, however, the liquid being pumped cannot be diluted with water the lantern ring is replaced by two further rows of packing with stoneware plugs for closing the connections. Below the hood casting, alongside the casing and dilution water drain connections, is a stoneware drip tray, whilst the split gland is either of vulcanite or of stoneware, reinforced by a metal flange. Further, the large diameter shaft is of mild steel, and the two bearings comprise a double thrust and journal unit next to the pump and a roller unit at the driving end. Additional details include a water thrower and dust cap of the labyrinth type to prevent acid liquid entering the bearing from the gland, whilst each bearing also has grease nipples, and the shaft between is completely protected against any accidental contact with the acid.

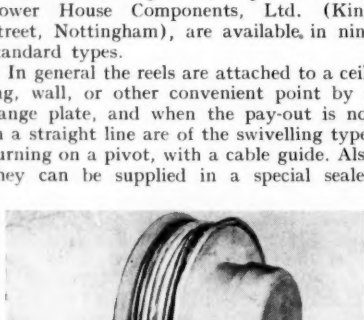
SELF-WINDING CABLE REELS.—For all kinds of equipment driven by electricity involving position movement and adjustment, such as for example conveyors, machine tools, and portable welding sets, as well as portable hand tools and portable and adjustable electric lights, loose cable has to be used for the supply of the current.

For this purpose a notable advance is represented by the " Wayne " self-winding electric cable reel, on which the cable winds or unwinds, having a spring mechanism in an enclosed casing, on the same principle as the spring roller blind. That is the cable is paid out against the operation of a spring, which always maintains a suitable tension, without any undue slack or sag, and when the latter decreases the cable automatically rewinds by the action of the spring. By this means no trailing cable is necessary and there is a great increase in the life, because of the almost complete elimination

of accidental mechanical and other damage, such as by " kinking " or being run over by trucks, or brought into contact with oil and water.

The self-winding reels, a production of Power House Components, Ltd. (King Street, Nottingham), are available in nine standard types.

In general the reels are attached to a ceiling, wall, or other convenient point by a flange plate, and when the pay-out is not in a straight line are of the swivelling type, turning on a pivot, with a cable guide. Also they can be supplied in a special sealed



steel plate casing for operation in inflammable atmospheres, such as obtains in the plastic, cellulose, rubber, chemical and allied industries, so that any stray spark cannot cause an explosion.

Typical is a recent installation in a cellulose impregnating plant, the casing having a slot through which the cable, ½ in. diameter, runs as it winds and unwinds on the rotating drum. Also the slot is provided with a series of rubber diaphragms in line, which allow of unrestricted movement of the cable, but form an effective gas seal, so that a spark inside the casing could not ignite the vapour outside. This is an indication of the flexibility in application of self-winding reels of this type, whilst another type of protective casing available is for use in a dusty atmosphere such as with coal, cement, lime and chalk, and it may be stated also that each installation is designed to suit the individual conditions.

MAKING PLASTICS IN SOUTH AFRICA.—New plastic products are now being made by a Johannesburg factory, which at this stage is going to produce only items of value to the war effort. These plastics are made entirely of African raw materials and among the items being produced are dielectric products consisting of heavy switch mounting boards, tubular and extruded rods. It also makes many moulded articles, including containers.

A Johannesburg chemist has invented a new form of powder from which plastics can be manufactured, all the ingredients of this powder being of South African origin. The powder, when pressed and subjected to heat, has similar properties and appearance to the high-grade imported plastics. The finished product is claimed to be acid-resisting, heat-resisting and dielectric. The powder is suitable for moulding battery cases, door fittings, bottle stoppers and other plastic fittings. It is pointed out that the production of plastics of purely South African origin should prove a boon to manufacturers, as plastics can often be used as a substitute for other materials which may no longer be obtainable.

The plastic, L.I.R.I. 568, is claimed by the Leather Research Institute in Grahamstown as one of its most important discoveries. Dissolved in a suitable solvent, this plastic can be used for binding and forming fibrous materials such as leather and felt. It is being used for various operations in the South African footwear industry, which is suffering from a shortage of the more regular materials. At first this plastic was made by the Institute, but a Port Elizabeth firm has now put up a plant and is beginning to produce it on a large scale.

LUBRICATING PLASTICS.—The use of plastics as a substitute for metal in mechanical equipment has brought the lubrication of such material into greater prominence. One of the advantages of a fabric plastic is that it can sometimes function dry against steel and various non-ferrous alloys. An example is that of bushes where continuous rubbing is not experienced, or, if rubbing does take place, it is not continuous and of high speed.

Where it is employed as a straightforward journal bearing and is subject to continuous rubbing against a shaft, it is sometimes necessary to use a coolant such as water. It is, of course, well known that oil or grease is generally unsuitable for fabric plastics which limits the lubricants to those of non-petroleum origin.

An interesting development in this field is dry lubrication by means of films formed with " dag " colloidal graphite. Dispersed

in a volatile carrier such as acetone, the colloidal graphite is brushed on to the fabric plastic surfaces after machining, and the carrier evaporates to leave a thin slippery film. The kinetic coefficient of friction of such a dry film compares favourably with a boundary film of lubricating oil, while static friction is also low.

In some cases a dispersion of " Aquadag " colloidal graphite in water has been employed, but the type of carrier used for the colloidal graphite depends on local conditions. Another possibility is the incorporation of this product dispersed in acetone into a synthetic resin which can then be applied to the surface of the plastic bush, bearing or whatever it may be.

An advantage of the above technique is that the graphite film formed with the colloidal product adheres well to the surfaces on which it lies. The life would depend on rubbing speeds and other factors, but for a locating bush or similar part where continuous rubbing is not experienced, or where the loading is light, the life of such a film would be considerable.

Further details may be obtained from the Technical Department of E. G. Acheson, Ltd., 9, Gayfere Street, London, S.W. 1.

ENGINEERING BULLETIN

The September issue of this valuable war-time Bulletin issued by the Ministry of Labour and National Service contains an article of direct interest to all those plastic concerns making or repairing their own moulds or who are engaged in machining laminated material, cast resins, etc. Under the title of " New Life for Old Cutting Tools," it tells of the best methods of conserving high-speed alloy steel. There is no need to emphasize the importance of prolonging the life of every cutting tool and to make stocks go farther.

There is, indeed, a special service for the salvage of this valuable material and worn and broken tools and ends should be sorted and all that cannot be reused should be turned over to Government collecting centres, addresses of which can be obtained from the Controller of Jigs, Tools and Gauges, 35, Old Queen Street, London, S.W.1. Very good prices are paid.

As for material that can be reused in the factory, the following notes are included :— Old and broken cutters and ends should be softened, in batches, and returned to the tool store for cutting into tips for new tools or repair of tools as required. The tips are brazed and hardened on high tensile steel shanks, prepared and machined for the purpose Shanks of worn-out ready-made tipped cutting tools may be used.

Contrary to a general assumption, there is nothing new or revolutionary in the practice of cutting up old solid cutters to make new tipped tools. This was introduced into large works as an economy measure some 20 years ago, and has been well tried and established in practice.

Other economies to be observed include the use of carbon steel drills and other tools for many jobs for which H.S. steel is now unnecessarily used. In the same way, case-hardened steel cutters—milling-hobs, reamers and other tools—can be used for many operations on M.S., and are certainly as good as H.S. steel cutters for machining light alloys.

GOVERNMENT CONTROL AND COSTING.—The " Financial News " has brought to notice some of the complaints made by industrialists of wastage in time and labour caused by the cost investigations of Government departments. It cites an extreme case brought to the public notice by the chairman of British Industrial Plastics, Ltd., which submitted to the costing of its entire output and that of its subsidiaries, so that the interested Government department might ascertain the figure of overheads appropriate to a small contract representing a fraction of one per cent. of the company's yearly turnover. The amount at issue could not be more than £100, compared with the sum of £96,750 reserved for taxation in the last balance-sheet.

COTTON EXHIBITION. — A cotton industry war exhibition was opened last month in Manchester by Mr. Hugh Dalton, President of the Board of Trade. Excellent examples of cotton sheet impregnated with synthetic resin and some of the war materials made from it were on show.

TRADE NOTES

British Xylonite Co., Ltd., have paid an interim dividend of 2½ per cent. (same as last).

Erinoid, Ltd., have paid a dividend of 10 per cent. on the ordinary shares. The annual general meeting will take place on October 28.

CHANGE OF ADDRESS

The Building Centre is now situated at 23, Maddox Street, London, W.1 (late Galleries of the R.I.B.A.). Telephone, Mayfair 2128-2129.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XII.—High-frequency Electrothermics in the Plastics Field

THE youngest and the most promising branch of industrial electricity is that of high-frequency electrothermics. High-frequency currents allow the realization of the inductive thermal effect within the treated object, which may be either an electrically conducting substance or a dielectric.

This possibility in many instances revolutionizes the entire technology of manufacture. It often reduces the time cycle of the operation tenfold and even hundredfold, and the treated articles can have imparted properties to them that are unobtainable by the application of other methods. As a rule, for heating purposes the high-frequency current is a considerably more suitable form of energy than the ordinary current of power frequency (50 cycles per second).

As is well known, metallurgy first employed electrothermics, where it has been utilized to the greatest advantage for effecting the so-called case-hardening or surface cementation of metals, apart from the inductive heating for forging and stamping operations. Hence it is evident that in a similar way high-frequency electrothermics thus offers an opportunity to the plastics technologist for widening the scope of his activities to his own field. Doubtless, high-frequency heat treatment of plastic materials, particularly in conjunction with various fillers, such as metal powders and the like, opens up entirely new prospects in the industry. In many instances, as in the case of thermoplastics, this permits their use as mere binding bases, or bonding and densifying agents for fibrous substances, thereby extending the fabrication technique by thermo-welding, embossing, roller-coating and other operations.

Heat Transfer in Plant Equipment

As has already been pointed out by the author in Section I of this work, one of the chief difficulties of plastics production arises out of the basic problem of heat transfer through various parts composing the manufacturing unit, the equipment and the body undergoing treatment.

Owing to low heat conductivity, inherent to resinous substituents, it is extremely difficult to obtain a perfectly homogeneous product, with the result that, because of uneven distribution of stresses, the physical properties of structure may gravely be impaired.

The motivating force of chemical processes is a free energy of reacting substances and the free energy is a function of the temperature. At the same time the temperature is the universal accelerator of chemical interactions.

Consequently, the problem of communicating the heat to, or abstracting it from, the chemical plant must be uppermost in approaching engineering design, particularly of the equipment for the treatment of such heterogeneous multi-component systems as are met with in the plastics industry.

Furthermore, apart from this technical aspect, the economic effect of heat transmission should not be overlooked, the significance of which can be readily appreciated if we recall that the quantities of thermal energy consumed in chemical production form, on the average, from 15 to 20 per cent. of the manufacturing costs.

Therefore, a rational planning and exploitation of any chemical engineering installation is inseparable from the correct selection of the most suitable source of

heat and provision for its satisfactory transfer throughout the production unit.

Mechanism of Heat Transmission

The thermal conditions encountered in processes of applied chemistry are extremely diverse, the temperatures ranging from sub-zero region to high levels ascending to several thousands degrees Centigrade. The materials under the treatment in the chemical plant may be at rest or in motion, in all states of aggregation, the heat exchange being effected either directly from hot bodies to cold, or through partitions; the sources of heat vary from the naked fire to heated fluid media, viz., water, oil, electricity, the heat of chemical reactions.

The complicated question concerning the flow of heat in chemical plant is at present intensively studied, various theories being constantly checked by vigorous experimental tests, and the valuable data thus derived is turned to account in order to increase the industrial efficiency.

There are three ways of transferring heat:—

1.—Conduction—the transmission of heat energy in the direction of diminishing temperature levels, which is conditioned by the physical contact of the elements constituting the system, not free to move relative to one another; this is the heat flow through the resistance of a measurable thickness; retaining walls of the vessel and piping, thermal insulation, and the like.

2.—Convection—heat transfer in fluid and gaseous media owing to currents arising in these bodies due to the thermal agitation of molecules; this is heat transmission through the thermal resistance of unknown thickness: a liquid film on the surface of tubes, a gaseous film on the interface of apparatus, etc.

3.—Heat transfer through the various intermediate forms of energy, in particular, by means of radiation.

Newton's Law of Heat Flow

The first two methods of heat flow are governed by Newton's law, which, as developed in detail by Fourier and Poisson, may be formulated thus:—

The quantity of heat dQ (in calories) passing through a given section at right angles to the direction of the flow is directly proportional to this cross-sectional area A (in square centimetres), to the time θ (in seconds), and to the difference in temperature, dT (in degrees C.), along the path of flow, and inversely proportional to the thickness L (in cm.). The relationship of these factors is given by

$$dQ = \frac{K.A.\theta.dT}{L}$$

that is as: calories/per sec./per sq. cm./per °C./per cm.

Converted into the British Thermal Units, the foregoing expression becomes: B.t.u./per hr./per sq. ft./per °F./per ft.

This equation is very helpful in practical engineering calculations of heat transfer of plant equipment, especially in computing the area of heating and the thermal balance.

The temperature difference is determined by the operating conditions of the apparatus; the thickness of retaining walls depends, naturally, upon the mechanical strength and stability of the chosen constructional material.

The so-called coefficient of specific heat conductivity, K, denotes the quantity of heat (in the corresponding system of units) flowing in unit time through unit area in the direction at right angles to the latter, when the temperature of the path of flow is decreasing uniformly by one degree in passing from one point to another distant at unit of length. The reciprocal value, $\frac{I}{K}$, designates the thermal resistance of a given substance.

The coefficient of heat conductivity, which is determined by experiments, varies within a wide range for different materials, particularly for heat-conducting versus insulating bodies.

The dimensionality of the fundamental units involved will be readily apparent by reference to the thermal equivalent of an electric current in terms of Joule's law, which states that, if the total energy of the electric circuit is converted into heat,

the quantity of heat, Q (in calories) = j. × E volts × I amperes × t seconds.

The value of the constant j (i.e., 1 electrically defined international joule) is 0.2390 cal. per volt-ampere-second. Hence the power of current, or the work performed per unit of time, is: 1 volt-ampere = 0.2390 cal./sec. = 1 international joule/sec. = 0.00134 horse-power = 1 international watt.

Under certain well-defined conditions, the transformation of electrical energy into heat offers a convenient method for producing high temperatures.

History of the Development

The first utilization of high-frequency electrothermics in the plastics technology belongs to the French investigator, Leduc, who in his early works, in 1935, raised the question of radio-vulcanization of rubber and gave an account of his experiments in this sphere.

In one of his articles, Leduc[150] suggested a practical method for vulcanizing rubber articles in an alternating magnetic field; the heating is effected by means of inductive currents energized in the electro-conducting particles of the rubber mix. In another article Leduc[151] proposed a method for curing rubber in an alternating electric field, where the object under treatment was of dielectric nature.

Further information forthcoming from Leduc,[152] and other workers, including Du Pont de Nemours Co.,[153] U.S.A., deals in a general manner with the principles of applying high and ultra-high frequency waves to the vulcanization of rubber products, such as rollers, articles from latex, cementing parts of footwear, etc.

The problems of utilizing the ultra high-frequency electrothermics were subsequently tackled by Leduc at the London Conference on the Rubber Technology,[154] in 1938, and in the French Encyclopædia on the Technology of Rubber[155] issued the same year in Paris.

However, most of the information contained in the above publications has been confined to general remarks and, in the main, was characterized by the absence of concrete details as to the technique and methods of the application.

Advantages of H.-F. Vulcanization of Rubber

The principal advantages incident to the electro-curing of rubber by the ultra high-frequency currents are as follow:—

(a) The uniformity and speed of heating throughout the mass of the body.

(b) The ease of regulating the temperature of the article undergoing the treatment by means of varying the frequency and the power of the field, or, alternatively, by an appropriate selection of compounding ingredients of the rubber mix.

(c) The possibility of utilizing the heat generated in rubber under the action of high-frequency field solely for the operation on the body under the treatment, without wasteful energy losses for heating the moulds and platens of the press. These consume from 90 to 95 per cent. of the total thermal energy in the orthodox vulcanizing process.

(d) The radical reduction of curing time, particularly of massive articles; this is due to the fact that the increase of the temperature throughout the mass of the rubber material is accomplished very uniformly; the curing level is attained literally within a few seconds.

(e) Ease of application of the operating conditions, since they afford the possibility for developing a continuous vulcanizing process.

Notable Advances

The attractive prospects of various industrial uses of ultra high-frequency currents have met with a very early response in Russia, where their theoretical investigation and application to the manufacture of products derived from natural and synthetic rubbers and other processes have made remarkable progress.

Thus, for example, the researches of Morozoff[156] resulted in the possibility of using high and ultra-high frequency electric oscillations for the drying of cotton.

Further studies of the influence of ultra

high-frequency fields upon the physical and chemical properties of gelatine published by Sinitzin[157] in 1939, followed by the account of experiments performed by Voskresensky[158] on the action of ultra high-frequency currents upon the inversion of saccharose, were highly instructive. The foregoing works have established the absence of any influence of the ultra high-frequency waves on gelatine and saccharose, except a purely thermal effect caused by high-frequency electric oscillations.

Shortly afterwards a group of workers led by Selugin[159] revealed in a valuable monograph on the subject the results of their researches on applying high-frequency electric fields to the heating and drying of wood and other fibrous or granular materials.

The works quoted above contained for the first time the detailed information on the technique of application of high- and ultra high-frequency electrothermics, touching not only upon the problems of their arrangement, but also the questions of design for continuous processing machinery, providing for what might be termed line-production operating methods on the conveyor principle, estimation of the efficiency, power factor, practical instructions, etc.

Installations

The satisfactory results of experiments conducted in 1939 by Medvedchuk[160] and his collaborators marked an appreciable advance in the application of ultra high-frequency electrothermics to the treatment of both natural rubber and synthetic rubberlike plastics.

The above-mentioned work has vindicated not only the soundness of the theoretical interest displayed by some investigators, but the practical significance of the action of ultra high-frequency fields on high molecular systems in general, thereby paving the way for their further development.

As a source of the production of ultra high-frequency fields for these experiments, a 250 w. generator of the Holborn type was used, with the size of the condenser plates 5 by 12 cm., 15 cm. distant from each other, having the field gradient 450-500 V/cm., and 6 metres wavelength.

The arrangement of this installation for

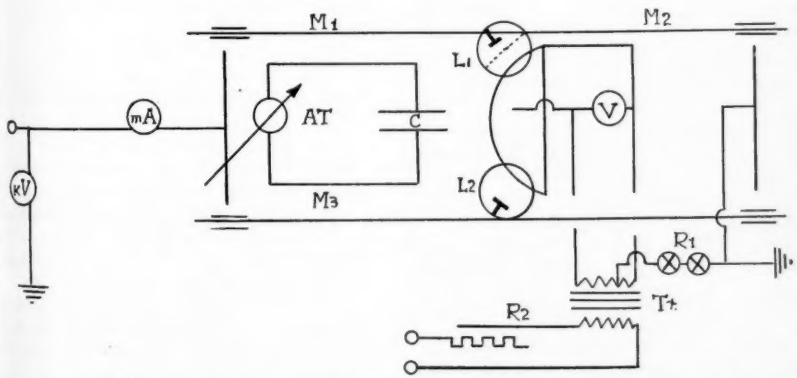


Fig. 1.—The basic diagram of a 250-watt generator (Holborn type) for the excitation of ultra high-frequency oscillations for the thermal treatment of high molecular compounds. It is particularly suitable for the welding of thermoplastics such as poly-acrylates, polystyrenes, etc., for the vulcanization of rubbers and for drying of wood, etc.

Key: L_1, L_2—generator valves; M_1—variable self induction of the anode condenser; M_2—same for grid condenser; M_3—same for secondary condenser; C—working condenser; R_1—valve generator of grid displacement; R_2—incandescence rheostat; Tr.—incandescence transformer; kV—kilovoltmeter of anodic potential; mA—milliammeter of the anode current: V—incandescence voltmeter; AT—heat ammeter indicator.

the experimental research is shown in Fig. 1, together with explanatory notes concerning the principal elements of the system.

Experimental Part

As objects for investigation have been selected the samples of the natural rubber (light crepe) as well as the sodium-butadiene rubber compounds, masticated with 5 per cent. of zinc oxide and an appropriate sulphur content.

The action of ultra high-frequency electric oscillations has been examined on both solutions of rubber in non-polar solvents (viz., benzene), and on the films derived from them. The rubber solutions have been prepared in 1, 2 and 3 per cent. concentrations. As film-forming compositions, solutions of 5 per cent. of natural rubber and 8 per cent. of synthetic rubber in benzene were used.

Ten millilitres of each solution were poured into crystallizers filled with water. The size of the crystallizing vessels in all experiments was the same: 20 cm. in diameter. The solvent (benzene) freely vaporized, and on the surface of the water was formed a thin rubber film. On removal from the crystallizer, the film was powdered with a small amount of talc to prevent tackiness. The films were then placed in a vacuum-desiccator, where, under reduced pressure over calcium chloride, they were kept until constant weight was reached.

Following this, the films were subjected to the action of the ultra high-frequency electric fields. The measured amounts of rubber solutions were poured into glass cylinders fitted with ground seals. These cylinders were then suspended parallel with the plates of the condenser by means of silk threads.

Results

The above-described experiments for examining the influence of ultra high-frequency electric currents upon the natural and synthetic rubbers, in solutions and in the form of films, have demonstrated a series of positive results.

On the basis of analytical data as revealed by determining free sulphur in the rubber solutions and films obtained from them, prior to and after the treatment by the high-frequency fields, it is possible to draw the following conclusions:—

(a) The ultra high-frequency electrothermic process is an efficient tool for effecting the vulcanization of both the natural and synthetic rubber products prepared in the form of solutions in organic solvents as well as fine films.

(b) The curing process proceeds at a very rapid rate: quite an adequate effect of the treatment is obtained in one minute.

(c) The quantity of the combined sulphur increases as the duration of the action of ultra high-frequency currents lengthens.

Electrothermics in Plastics Field

From what has been said above it will be seen that in order to appreciate the rôle of high-frequency electric fields in their applications to coatings, it is well first of all to survey the utility of electric heat in the plastics industry in general, for no sharp line of demarcation can be drawn between curing the three-dimensional plastics and fine films made from them.

Since rubber technology presents the most comprehensive type of plastics manufacture, it will be very helpful to discuss the problem of electric heat in conjunction with its basic technique.

The vulcanization of moulded rubber articles may be regarded as the main chain in the entire process of production and at the same time one of the most difficult from the point of view of actual operating conditions.

The crowded rows of the vulcanizing presses with open platens dissipating wastefully great quantities of heat by radiation into the surrounding air, the noise of the escaping steam, pools of the water around the presses, concentration of bulky air-conditioning plant, ventilating pipes, etc.—all this creates an unfavourable atmosphere, affecting the works efficiency.

Moreover, the non-uniform heating of platens owing to clogging by the particles of dust in the channels of platens and the accumulation there of condensate lead to inferior quality production and to increased consumption of steam.

Hence it is clear that the hydraulic press, under such conditions of manufacture, is used unproductively during the curing operation.

Electrothermic Methods

The application of electrothermics to the plastics fabrication technique, as typified, for example, by the vulcanization of rubber, pressure and injection moulding of synthetic resins, activation, fusion and curing the thermoplastic cement compositions, etc., can be accomplished by the following three methods:—

1. Heating by the electric current of the resistance elements of the circuit. In this case the heat released by the resistance elements is communicated to the plant equipment, in which the process is conducted (e.g., autoclave, platens and moulds of the press, etc.).

2. By inducing eddy or Foucault currents, set up by an alternating field, either in the metal of the apparatus, in which the operation is performed (e.g., the platens and moulds of the press, etc.), or within the plastic body itself by making it electro-conductive through the admixture of various "energy absorbers," such as metallic filings, powders, electrolytes, etc., and by producing the heating effect due to the process of hysteresis.

3. By excitation of the electromagnetic oscillations of ultra high-frequency, in which event the treated plastics form a dielectric between the plates of the condenser; in this dielectric an effect will be produced similar to the hysteresis of iron; this effect, known as dielectric hysteresis, involves the loss of electric energy and a corresponding heating of the dielectric (resulting in the "radio-vulcanization" of rubber, thermosetting of resinous coatings, etc.).

On account of their importance we will consider the above applications of electrothermics in more detail.

In the first case, when the source of heat is the electric current passing through appropriate elements of resistance, the whole arrangement is, in principle, similar to the design of an electric iron; with regard to the construction such a heating can be accomplished in the following manner:—(a) The resistance elements are placed into the platens of a hydraulic press either directly into steam conduits (in the event of adapting the platens of the available presses), or into specially drilled channels.

The elements of resistance may be made to conform to any design (e.g., in the shape of strips, spirals, plates and the like), using various materials, such as nickel-chromium and other alloys.

With equipment of this type the thermosetting operations on plastics, such as the vulcanization of rubber, etc., will have to be carried out in the same way as it is done with the steam-heated hydraulic press.

Whilst the application of this method of electric heating may be recommended for laboratory practice, its suitability for industrial production is doubtful on account of thermal losses (just as with the steam processing); the use of costly electric heat is unjustifiable.

(b) The elements of the electrical resistance are inserted directly into the body of the mould, leaving the platens of the press cold. By heating the mould the resistance elements thus effect the curing of plastics compounds contained therein.

This mode of heating the moulds affords the possibility of thermal treatment of plastic products (e.g., vulcanization of rubber, etc.) pre-formed outside the hydraulic press. In this case the mould should be provided with a suitable locking device in order to ensure the maintenance of imparted pressure during thermosetting operation, after it is removed from the press.

Owing to the operating difficulties arising from introducing electric current into each mould (damage of conductors, accumulation of dirt upon electrical contacts, the network of conductors connect-

ing each mould and obstructing the freedom of movement by the operator, etc.), it is not to be expected that such a design will be adopted for industrial uses.

A variant of the same principle is to arrange the supply of the electric current to the resistance heating units, embedded in each mould, by means of copper or aluminium bus-bars placed within platens. In this event the heating element of the mould will be fed with the current from this lead-in only during the pressure operation performed on the mould by the platens of the press.

Although such a modification, from the thermal standpoint, is an improvement over the method of heating through the resistance units enclosed in platens of presses (due to drastic reduction of heat losses), this arrangement could hardly be very effective (with the possible exception of some individual cases) on account of the deleterious action of plastic particles (quite unavoidable) upon the contact between the lead-in for the current (within the platen itself), and on the moulds; for these reasons it is unlikely that this design will find wide applications in industry.

(c) Lastly, the thermosetting of plastic products may be carried out by the convection and radiation caused by the resistance units, through which is sent electric current of suitable strength. In the latter case the plastic compositions may be cured both in the moulds as well as in their absence.

A typical example of utilizing this mode of treatment of plastics is the electro-vulcanization of rubber articles in large-scale production of seamless thin-walled goods.

Inductive Heating

Passing now to the consideration of the second method of electrothermics, namely, through eddy currents produced by electromagnetic induction, attention should be drawn to the following promising development.

As a result of analysis of the advantages and shortcomings of different electrothermic methods in the rubber technology, Masloff, in Russia, hit upon a very interesting idea.

To avert numerous losses and waste, he proposed to separate the thermal operation from the hydraulic press, employing the latter merely as a pressure tool for pre-forming, while effecting the vulcanizing process by means of inductive heating of moulds outside the press.

Experience showed that such a division of the process appreciably cuts down the number of hydraulic presses, reduces the floor area required for their erection, creates healthier working conditions, and leads to a higher output and superior products.

Electrical Equipment for Inductive Heating

The induction electric installation, as originated by Masloff[161] at the beginning of 1937, is depicted in Fig. 2; although it can be adopted to higher frequencies, it has been designed for 50 cycles/sec. Its application is for the electro-vulcanization of various articles of footwear, viz., goloshes, etc., coated and impregnated textile fabrics, belting, etc.

Induction heating by the electric current of ordinary frequency, as initiated by Masloff, can be realized by means either of a single-phase inductor, or by applying the rotating magnetic fields of the three-phase current.

The single-phase inductor represents an air-core induction coil of suitable size and design, within which are moved the moulds. On impressing the alternating electric pressure to the coil, the eddy currents are induced in the moulds, which are heated thereby to the required temperature level.

As has been mentioned earlier, the pressure stage and the curing operation with this kind of equipment are performed separately. The moulding of the charge is carried out between the cold platens of the press by applying the pressure for about 15 to 30 secs.

To maintain the requisite pressure within the mould, upon removing it from

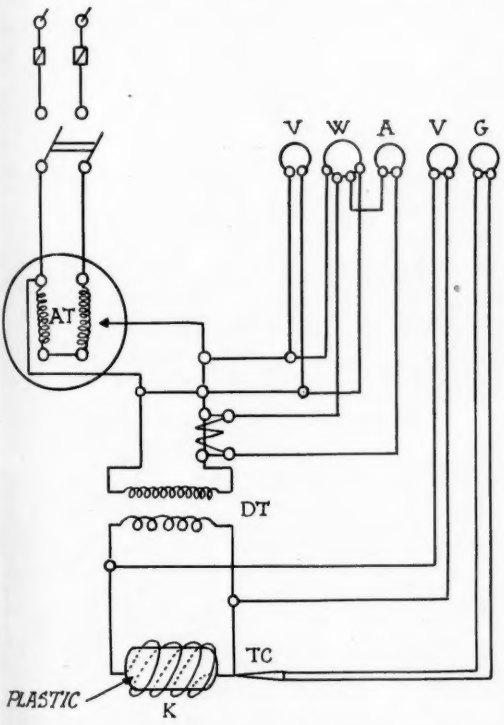


Fig. 2.—Diagram of connections for induction heating of plastics by a continuous process on the conveyor system. AT—auto-transformer; DT—step-down transformer; K—induction coil; VV—voltmeters of low and high sides of the step-down transformer; TC — thermocouple needle; G—galvanometer; A—ammeter; W—wattmeter.

the press, it must be provided with a special locking device, which is capable of automatically closing. The main point is the necessity of locking the mould.

After the mould has been properly locked, it is transferred to the second stage of manufacture, when electro-curing is effected by heating the plastic articles moving on a conveyor-belt through the solenoid, as indicated in the diagram of Fig. 2. The coil may be made of hollow copper or alumininm tubing and can be kept cold by means of suitable cooling media, such as water, carbon dioxide, etc.

On terminating the vulcanizing process, the mould is opened, the finished product is removed, and the new charge of rubber (or other plastics) is introduced into the mould for the next operation.

Manufacturing Advantages

The experimental production with such an equipment revealed a number of advantages, which are summarized below:—

(a) A single-phase inductor, while heating the moulds, remains itself cold.

(b) At the same time it is not connected mechanically with the moulds and takes very little space.

(c) The average energy consumption for vulcanizing, for instance, such an article as a rubber golosh, is of the order of 0.42 kwh.; the power input of the installation is then equal to 72 kw. (with the application of condensers), with the output of 1,900 goloshes daily, or at 380 kw. it gives output of 10,000 goloshes during the same period.

(d) The fine adjustment of the tem-

perature by appropriate electrical devices.

(e) The drastic reduction (approximately 30 per cent.) of the works floor area required for erecting the production plant.

(f) The radical decrease in the number of hydraulic presses in need of repair.

(g) Elimination of waste of plastic.

(h) Considerable amelioration of labour conditions.

The production is simplified and can be completely mechanized, thereby supplanting the lengthy, bulky and unwieldy steam equipment by a speedy electrified process.

The manufacture of this type may quickly be organized at any point where an electric transmission line is available.

In fact, one of the principal merits of the inductive heating of plastics in the single-phase inductor is characterized by the possibility of applying the electric current of the usual industrial frequency, that is, its direct connection with a low-voltage factory grid, dispensing with the installation of special generators.

In the light of the above considerations it is clear that the inductive heating in the plastics field deserves the close attention of technologists, particularly in mass-production of specialized classes of plastic goods, such as pressure- and injection-moulded rubber footwear, activation of adhesive films in laminations, and others.

The apprehension felt in some circles in regard to expense of the electrothermics compared to steam heating of plastics are dispelled by Russian experience, the results of which have demonstrated that by the switching over to the inductive treatment the cost of making the rubber goods is reduced.

Heating by Polyphase Inductors

There is also another possible method for producing inductive heating effect. This is by employing the polyphase system.

The inductive heating of plastics by means of three-phase current is based on the principle of the functioning of a three-phase asynchronous motor. If the rotor of such a motor is replaced by the moulds (with the locking device) fixed around the inner circumference of the stator, Faucault currents, induced in the metal of the moulds, produce the heating effect necessary for vulcanizing the plastic charge.

The tests carried out by Professor Turlygin in the Moscow Power Institute have established that the thermal capacity of the three-phase arrangement for curing the rubber in moulds is inferior to that of a single-phase inductor. Hence further work on a three-phase equipment is needed.

The H.F. Condenser Field

The thermal treatment of plastics by the third method, i.e., by application of ultra high-frequency oscillations, is superior to other methods, since in this case the electric field heats directly an article due to dielectric hysteresis.

The simplest scheme for obtaining the heating effect by this method is an ordinary parallel plate condenser with the plastic compound serving as dielectric.

Under the influence of ultra high-frequency field the plastic object is rapidly heated in a perfectly uniform manner. It should be noted, however, that the shape of an article undergoing the treatment is an important factor: with complicated contours the intensity of heating becomes non-uniform at the cross-section of the body.

The experiments of Professor Turlygin showed that the heating effect of this equipment causes the rubber to flow within three to four minutes at the frequency of 15 megacycles per second.

According to the above author, the power factor of the heating arrangement in the plant of this type is 0.8, and that of the generator is 0.4; consequently, the power factor of the entire installation is equal to 0.32.

This figure should be regarded as law, since the power factor of a single-phase inductor at commercial frequency attained the value of 0.54.

This emphasizes the need for directing the efforts of designers towards the improvement of the power factor of such

an installation and the regulation of electrical energy communicated to the body under treatment.

Hence, in order to obtain a clear idea of the significance of ultra high-frequency electrothermics in actual practice it is well to bear in mind that, side by side with possibilities, it has a number of problems and difficulties, both of the general and special nature arising from the application to plastics.

The Electromagnetic Spectrum

All radiations emitted by atoms and molecules and propagated through space with the velocity of light as oscillating electric and magnetic fields at right angles to one another, cover a very great range of frequencies, or wave-lengths. The velocity of propagation, C, the wave-length, λ, and the frequency, V, are related by the fundamental equation $C = V\lambda$, which holds for all waves.

Proceeding from the lowest level of this range, with the ordinary frequency (50 cycles/sec.) of commercial alternating currents (with long waves of the order of many thousands kilometres), this range extends to frequencies of approximately $V = 10^{23}$ cycles per sec. and wave-lengths $\lambda = 10^{-3}$ cm. The region of frequencies above 10,000 cycles/sec. is generally known as the high-frequency region, comprising long, short and ultra-short radio waves (with V from 10^4 to 10^8 cycles/sec.), followed by the Hertzian waves, and passing into the region of the shortest electric waves, which can be produced by the oscillation of macroscopic circuits. The highest frequency so far attained in the laboratory is about 10^{12} cycles/sec.

These ultra-short electric waves (not to be confused with the ultra-short radio waves) merge into the heat rays or radiant heat resulting from the thermal agitation of molecules. The infra-red rays that border on the visible region, with wave-lengths affecting the human eye (forming only small bands of wave-lengths between 0.4μ and 0.8μ), followed by the ultra-violet region, are characterized by frequencies (above 10^{12} cycles/sec.) of molecular and atomic origin.

Then we have X-rays (or Röntgen rays), with frequencies up to approximately 10^{19}, extending into the region of the so-called γ-rays produced by the spontaneous disintegration of atoms or radio-activity. Beyond this high-frequency end of about 10^{23} lies, finally, the region of cosmic rays, arriving at the earth from outer cosmic space.

Oscillatory Systems

Since the energy is used up at a very rapid rate in an oscillatory system, it is necessary to supply power continually in order to prevent the oscillations from dying out. This is achieved by coupling the oscillatory circuit to an exciting circuit, which must contain the source for generating oscillations of the required frequency.

On account of the great theoretical and practical importance attained by high-frequency oscillatory systems, a brief outline of its principal features may be found helpful.

Among various methods for producing these oscillations (e.g., spark or impulse excitation, the oscillating electric arc, high-frequency A.C. machines, etc.), thermionic valves are nowadays by far the most convenient source for exciting high-frequency oscillations, as exemplified by the modern valve generator.

The remarkable successes achieved in the manufacture of powerful valves had the result that 1 kw. of high-frequency current (up to 10^7 cycles/sec.) costs barely two to three times the energy derived from current at 50 cycles/sec. The cost of the initial outlay for the installation with electrical input of 1 kw., including the oscillatory circuit condensers and heating appliances, usually does not exceed £50.

The modern valve generators are simple in design and dependable in service. They can be made from a few fractions of the watt up to 1,000 kilowatts.

A high-frequency oscillatory installation consists of the three principal parts: (i) rectifier, (ii) generator, and (iii) secondary or irradiating circuit.

Without going here into details relating to negligible losses of energy involved in converting and rectifying the current employed, let us consider the final stages of energy transformation.

The power input communicated to the generator is divided into energy dissipated by the anode and that led into the primary oscillatory circuit. The amount of energy transferred from the primary circuit (or contour, as it is sometimes termed) into the secondary circuit, in its turn, depends upon the nature of the coupling between the two circuits and on the correctness of tuning; actually, the total energy transfer from the primary into the secondary circuit cannot be realized in practice.

Furthermore, the volume of energy, which is absorbed by an object placed within the condenser of the secondary circuit, depends on: (a) the frequency of the oscillations, (b) dielectric properties of the heated body, (c) the geometric configuration and dimensions of the object and the condenser plates as well as the distance between them.

Whilst these factors do affect the behaviour of the secondary circuit, they exert no bearing upon the régime of the primary circuit.

Whence it follows that one of the main tasks in the designing of such systems is the finding of the methods for efficient regulation of energy transmission from the secondary circuit to the object under treatment.

However, this problem still remains to be solved, and the various suggestions put forward by some workers as yet fail to yield concordant reproducible or practical results.

An important advance in exploring the nature of processes involving the application of this type of installation to the treatment of plastics was furnished by the recent research of Professor Zaionchkovsky[162] and his co-workers in Russia.

This work was a direct outcome of the study of the thermal action of the ultra high-frequency fields upon synthetic rubbers, free from sulphur and accelerators, but containing a considerable proportion of carbon black.

Press Experiments

The experiments have been performed in a press, which has been specially equipped for the heating by means of ultra high-frequency currents. The arrangement of the press, together with the ultra high-frequency installation as well as the measuring and controlling devices, are schematically shown in Fig. 3.

The electrical input, equal to 150 w., of the generator actuating the primary oscillatory circuit (1), through the secondary circuit (2) was communicated, at frequency 4.6×10^8 cycles/sec., to the condenser plates (3), for producing the heating effect upon the treated object (4) which was kept under suitable pressure transmitted through the medium of supporting wooden blocks (5). The thermocouple, in the form of a needle, served for the measuring of the temperature of the body under treatment, which was made in the absence of the field by indications of a sensitive galvanometer (6).

The process of curing synthetic rubber by this means, in the absence of accelerating agents, was designated by the authors as thermovulcanization. The above treatment, in addition to examining the behaviour of sulphur-less sodium-butadiene compounds, was also extended to a wide range of other synthetics, including the most diverse polymers of the divinyl and polydiene types.

It will be obvious from these experiments that this kind of installation is admirably suited for the thermal treatment of many compounds, thermoplastics, synthetic or natural resins, various derivatives of cellulose, etc.; this plant equipment is particularly fitted for the efficient production of composites, such as multi-plywood laminates, as illustrated in Fig. 3 for bonding of lenses in safety glass, electrical insulants in sheet, tube or rod shape, condenser impregnated paper and pressboard, heavy leather belting, wallboard, rigid or flexible, etc., by the activation in the high-frequency field

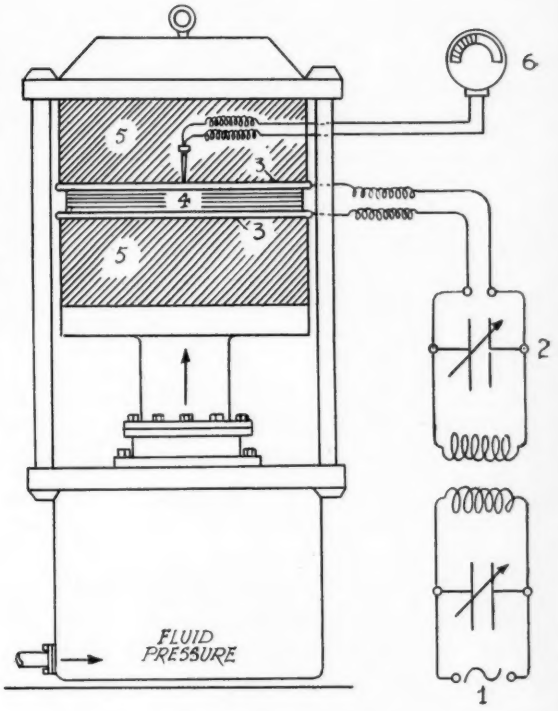


Fig. 3.—Diagram of arrangement for the thermal treatment of resinoids in a high-frequency electrical field. Key: In the press is a five-plywood laminate bonded with a synthetic resin film. 1—the primary oscillatory circuit actuated by a suitable generator; 2—intermediate circuit; 3—aluminium condenser plates; 4—five-plywood undergoing HF treatment; 5—supporting wood blocks; 6—thermocouple needle indicator.

of resinoid cement films previously applied to the surface.

Problems of High-frequency Electrothermics

From the analysis of data as presented above it is logical to conclude that the task of utilizing ultra high-frequency electrothermics in the plastics field, whilst undoubtedly of great promise, appears to be, in the light of existing knowledge, rather complicated, having a series of practical difficulties and is, therefore, just at the gate of possible developments.

For these reasons let us confine the present discussions to formulating those questions, which will have to be solved in the immediate future, and which are already receiving a considerable amount of attention by scientific workers.

A.—The factor of importance is the proper design and selection of material for the construction of moulds, in which the thermal treatment of plastic substances (e.g., vulcanization of rubbers, curing of resinoids, etc.), in the ultra high-frequency fields, is carried out.

Mass-produced articles, for which they are particularly suited, are usually treated in metal moulds. However, it has been found that, under the conditions of the ultra high-frequency field, the metallic mould is inapplicable, demanding a different material of dielectric nature, which is, moreover, very resistant to heating by the ultra high-frequency currents.

According to experiments carried out lately by Ermolaeff[163] and his co-workers at the Institute of Chemical Technology in Leningrad, a suitable substance for such a purpose is "Micalex," which con-

sists, mainly, of mica bonded with glass; it possesses an adequate mechanical strength, thermal stability, low heat conductivity, and remains almost unaffected under the action of the ultra high-frequency fields; its chief drawback is brittleness, which might restrict its wide use in the fabrication of moulds if they are made entirely therefrom. Nevertheless, a suitable combination of metal with "Micalex" can (in many instances) facilitate the choice of structural design for moulds for massive articles.

B.—The question of improving the serviceability of the secondary circuit, the application of which introduces some difficulties and appreciably lowers the power factor of the installation, is of very great significance. The problem of design of special condenser plates for treating bodies of intricate shape is also of primary consideration.

C.—It is important to find out the most suitable type of measuring instruments for determining the quantities of energy absorbed by an irradiated object, and to develop the appropriate methods for safeguarding uniformity of heating, regardless of its configuration. The solving of this problem will assure the ease of regulating the thermal treatment of plastic articles having different shapes, thus preventing overheating due to concentration of the electrical energy at any one point, and will afford the possibility of continuous precision control of the temperature without causing damage to the product.

D.—The remainder of the questions, either unsolved or only partly solved so far, such as the safety of the installation (particularly when the platens of the press are made to function as the condenser plates), the study and utilization of a specific action (other than heating effect) of ultra high-frequency electric fields, and the selection of the optimum frequency range best suited for individual cases, the development of principles of formulating the compounding ingredients of the plastic charges to be treated, etc., can be settled either in the course of actual production or by means of pilot plant.

It must also be recognized that most of the unsolved problems are of the "interdepartmental" character, left at present unattended either by the radio physicist or by the chemical engineer, and could be speedily disposed of, provided that they are approached on the basis of co-operation.

For example, the application of ultra high-frequency currents to the production of laminates of the simplest rectilinear shape, to injection moulding of thermoplastics and rubber alone are sufficient in order to ensure the most efficient processing requiring very little area of the factory floor and compact equipment.

There will be no ground to regard electric power as an expensive source of heat if it be utilized exclusively for the thermal treatment of the plastic product.

The practical difficulties, as enumerated above, are not of unsurmountable nature and, consequently, must not be allowed to damp the initiative of plastics technologists; on the contrary, their very existence should only emphasize the timeliness for tackling this progressive idea in earnest in order to secure the full measure of benefit from its introduction into the plastics field, as was urged by the writer some years ago.[164]

(To be continued)

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Dispersions of Rubber

With Special Reference to the Use of the Beken Duplex Mixture

By H. J. STERN, B.Sc.

WITH the invasion of Malaya and the Dutch East Indies, the main sources of supply from which this country obtained its rubber are cut off. In addition, there are difficulties due to lack of shipping space. Under these circumstances, it is doubtful whether further supplies of rubber latex will be forthcoming for some time.

It should perhaps be explained that latex is essentially a watery emulsion of rubber. Even when specially concentrated it contains, as a rule, only some 60 per cent. of rubber, the remainder being chiefly water, which nevertheless occupies considerable space. Owing to its fluid nature, the storage and transport of rubber latex is more difficult than that of dry rubber.

The use of latex has, however, increased rapidly in recent years and many industries, both large and small, now depend upon it, having machinery for processing rubber in the liquid form only. With the cessation of supplies, these users are now compelled to make other arrangements and are considering the use of artificial dispersions.

Although the interest in artificial dispersions on the part of users in this country seems to be of recent growth and they have tended to use natural latex in the past, in fact the subject has received a good deal of attention, more particularly in the United States. Whilst it is not claimed that the list of references given below is exhaustive, it will be seen that for some time past numerous publications have appeared bearing on the subject. In addition, there is a large number of patents, amongst which may be mentioned in particular those of Pratt, which are operated in the United States by the firm of Dispersions Process Inc. Reading through the published literature on the dispersion of rubber, one is struck by the emphasis which is laid on what might be described as the chemical, as distinct from the mechanical, side. Great stress is laid on the ingredients to be used, but the machinery is usually dismissed in a few words.

Preparation of Artificial Dispersions

Before proceeding further, it may be as well to give a brief general outline of the methods by which artificial dispersions are prepared. There are two main processes, which may be described as the solution method and the direct dispersion method.

The solution method consists essentially of dissolving the rubber, or rubber compound, in any suitable solvent and emulsifying the solution. The solvent may then be distilled off. This type of process does not appear to have achieved any commercial importance (10). It is obvious that it has little advantage over the use of an ordinary rubber solution unless the solvent is recovered; and this recovery is, according to the published accounts, a slow and expensive matter. The direct dispersion process, on the other hand, requires no solvent and has already achieved considerable commercial importance, particularly in the United States. The method consists essentially of mixing an emulsifying agent (usually a soap) with the rubber, rubber compound, or reclaimed rubber. Sometimes, the soap is formed " in situ " by the successive additions of a fatty acid and an alkali. Water is then added to the rubber mixture, under suitable mechanical conditions, until a smooth emulsion is produced. Frequently glue, casein or other colloidal substances are used with the water in order to assist dispersion. It is important to realize that the addition of water or aqueous colloid cannot be made all at once and that the addition of a large mass of water to a lump of dry rubber mixture will not give an emulsion or prove satisfactory, even if the two ingredients are placed in a mixer. In the writer's experience and in spite of statements to the contrary, it is necessary to add the water very gradually with continual mastication of the mass. This at once raises a number of mechanical problems. When first mixed, the rubber, or reclaim compound, is tough and plastic. Next, a stiff paste is produced; then a creamy liquid and, finally, an emulsion not very different from natural concentrated latex. Thus everything depends upon the process of mixing being satisfactory and therefore upon the machines.

An obvious way of grappling with this problem is to use different machines at

different stages of the work. One of the very few articles that have been published on the subject of machinery ("Equipment for Producing Aqueous Rubber Dispersions," by John B. Tuttle) is significantly headed: "First Step of Process is Carried Out on Common Two-roll Mixing Mill; in the Second Step, a Two-blade Mixer is Used." Such a procedure, however, has many disadvantages. Apart from the labour and trouble of transferring the material in course of being processed from one machine to the other, there is the practical difficulty that many who may wish to prepare aqueous dispersions have no rubber mills and, quite apart from the heavy capital expenditure and high power consumption entailed, it is almost impossible to obtain such mills under present conditions. Tuttle gives some further details of what he describes as "the two-blade mixer" and refers to those made by Baker-Perkins Inc., Werner and Pfleiderer Company, Chas. Ross Sons and Co., and The J. H. Day Co. In his article there is an illustration of the Werner Pfleiderer mixer showing the usual double "Z" blades. There is also an illustration of the Charles Ross mixer, but only the outside can be seen. Provided the first part of the mixing operation is carried out on a two-roll mill, some kind of dispersion may certainly be produced on such machines. The Day "Mogul" mixer has been particularly recommended since it has been stated that the angle of the blades may be altered. An illustration of this mixer appears in the article by Rossman, but there is no description or reference to it in the text.

Results in Beken Mixers

In the experiments so far carried out, the "Beken Duplex" mixer has been found to possess several very important advantages in the production of aqueous rubber dispersions. In the first place, it is, as far as the writer knows, the only machine capable of giving efficient mixing at all stages of the process as described earlier. Thus, a single machine suffices. The use of the two-roll mill is avoided and there is no need to transfer the material from one machine to another. It should, however, be appreciated that, although reclaimed rubber may be worked directly in the "Beken Duplex" mixer, crude rubber should first be softened, either by mastication or by a heat treatment. A second advantage of the "Beken Duplex" mixer is that at the "crumbly" stage, when the mass breaks up, there is no tendency for it to be thrown out of the machine, or if not actually thrown out, to escape the action of the mixing blades. This is a great advantage over the machines hitherto used. To quote Tuttle: "The idea is that, in these mixers, the rubber is pulled apart rather than rubbed together." No doubt this is responsible for many of the problems previously encountered. A further disadvantage of the mixers previously employed is that their efficiency appears to depend upon the clearances (a) between the "Z" blades and (b) between the blades and the casing. It will readily be understood that, as wear takes place, these clearances increase and the sizes of the lumps found in the finished emulsion also increase. These lumps cannot afterwards be dispersed and they constitute a source of difficulty. With the "Beken Duplex" mixer, however, the action is not that of pulling the rubber apart, but rather one of squeezing it. The action of the "Beken Duplex" mixer is such that the mass is constantly masticated, the material being pulled down, as already described, into the mixing mechanism. Any wear that may take place is apparently without effect on the efficiency of the machine. Thus, a "Beken Duplex" mixer which had been used over a period of eight years for tests on a wide variety of materials, including many of a highly abrasive nature, produced a dispersion which was entirely free from the lumps to which reference has been made above. In the "Beken Duplex" mixer there is no possibility of any portion of the batch escaping incorporation in the mass.

In the mixing of dispersions of rubber, a point arises out of the fact that the original amount of dry material placed in the mixer is approximately doubled by subsequent additions and, during the whole of the process, there must be efficient mastication. The difficulty that either the machine will be insufficiently filled on starting the operation, or it will be over-filled before its conclusion, may be overcome by having the sides of the "Beken Duplex" mixer built up so as to increase the total capacity. This small addition can easily be carried out by arrangement with the manufacturers.

The above account is necessarily incomplete, since it represents the results of a comparatively few tests only. Nevertheless, experiments that have so far been made leave no doubt as to the utility of the "Beken Duplex" mixer and further work now in progress should enable even better results to be obtained.